ISSN (Print): 2077-7973
ISSN (Online): 2077-8767
DOI: 10.6977/IJoSI.202406_8(2)

International Journal of Systematic Innovation

VOL. 08 NO. 02
June, 2024

Published by the Society of Systematic Innovation

Opportunity Identification & Problem Solving

ISSN (Print): 2077-7973
ISSN (Online): 2077-8767
DOI: 10.6977/IJoSI.202406_8(2)

The International Journal of Systematic Innovation

Editorial Office:

- The International Journal of Systematic Innovation
- 6F, # 352, Sec. 2, Guanfu Rd, Hsinchu, Taiwan, R.O.C., 30071
- e-mail:editor@systematic-innovation.org
- web site: http://www.IJoSI.org
- Tel: +886-3572-3200

ISSN (Print): 2077-7973
ISSN (Online): 2077-8767
DOI: 10.6977/IJoSI.202406_8(2)

INTERNATIONAL JOURNAL OF SYSTEMATIC INNOVATION

CONTENTS

JUNE 2024 VOLUME 8 ISSUE 2

FULL PAPERS

DOI: 10.6977/IJoSI.202406_8(2).0001
C. Wang, T. Lee, et al./Int. J. Systematic Innovation, 8(2),1-16 (2024)

Developing favorite distribution mode of fresh food donations with grey relation analysis and TRIZ

Chih-Yung Wang[1]*, Tzong-Ru (Jiun-Shen) Lee[2], Ville Isoherranen[3], Shiou-Yu Chen[4]
[1]Department of Business Administration, Ming Chuan University, Taiwan.
[2]Department of Marketing, National Chuan Hsin University, Taiwan.
[3]School of Technology, Vaasa University of Applied Sciences, Vaasa, Finland.
[4]Department of Shipping & Transportation Management, National Taiwan Ocean University, Taiwan.
* Corresponding author E-mail: cyw@mail.mcu.edu.tw
(Received 19 December 2023; Final version received 8 March 2024; Accepted 8 April 2024)

ABSTRACT

Taiwan currently grapples with the intricate task of balancing its food supply and demand, resulting in the emergence of critical food surplus and waste issues. To address this pressing challenge, the government has turned to food donation initiatives led by public associations and private corporations to alleviate food waste concerns. Nevertheless, a significant obstacle remains in the form of the efficient and effective distribution of these fresh food donations from the supply side to the demand side. Therefore, this study aims to pioneer an innovative and optimized distribution model for fresh food donations employing TRIZ (Theory of Inventive Problem Solving) and grey relational analysis. Through an in-depth analysis of questionnaire data gathered from the public, this research uncovers the most favored distribution model, namely, "Government-invited third-party logistics providers (3PLs) to voluntarily manage distribution services, alongside the provision of preferential subsidies or tax incentives." Building upon these findings, this study offers valuable recommendations for governmental agricultural authorities and other stakeholders within the fresh food donation supply chain, serving as a cornerstone for sustainable food management practices.

Keywords: Fresh Food Donation; Distribution Mode; Disadvantaged Groups; TRIZ; Grey Relational Analysis.

1 Introduction

Food waste is recognized as a significant global challenge, particularly as the world population is projected to reach nine billion by 2050 (Garrone et al., 2014). Annually, approximately one-third of the food intended for human consumption worldwide does not reach our tables, being either squandered or misplaced (Mokrane et al., 2023). The annual worldwide food waste and loss could theoretically feed 939 million adults, assuming a diet of 2000 kcal and 50 g of protein per person each day (Abbade, 2020). In response to the growing need for a more sustainable future, food waste management has garnered increased attention from policymakers, NGOs, practitioners, and academics across various disciplines (de Hooge et al., 2017; Secondi et al., 2015; Seminar, 2016; van Giesen & de Hooge, 2019). Schanes et al. (2018) highlight the complexity of food waste and emphasize the integration of different perspectives to identify factors that contribute to or hinder its generation. This integrated approach also aids in designing surplus food distribution strategies in the final stages of the food supply chain.

To address the challenge of reducing food waste and promoting more sustainable food management, TRIZ is employed. TRIZ facilitates the development of more suitable distribution modes for fresh food donations. Wang et al. (2024) applies the TRIZ methodology to design a strategy that aligns with the real needs of users, enabling them to become active participants in the effort to reduce household food waste.

In Taiwan, the agricultural industry faces the issue of oversupply in certain types of fresh food, while various disadvantaged groups, such as low-income families, homeless individuals, and seniors living alone, suffer from food shortages. This imbalance between supply and demand leads to food waste. Although public and corporate food donations are commonly used to address these problems, logistical constraints make it difficult to effectively supply surplus food to the intended recipients, resulting in further food waste during the distribution process. Farmers with excess fresh food (with a focus on fresh fruits and vegetables) and the disadvantaged groups in need are scattered across different geographic locations, exacerbating the challenge of establishing an efficient distribution system that effectively connects supply and demand.

While some studies have proposed traceable supply chains for surplus food management (Aysoy et al., 2015), few have presented innovative distribution modes specifically for fresh food donations. Fortunately, the modern agriculture sector is known for its high level of innovation, which includes new production and processing practices, novel locations, and innovative supply chain designs that can serve as references. This study aligns with the perspective of Shukla and Jharkharia (2013), who argue that fresh food supply chain management should shift its focus from profit maximization to waste minimization to actively contribute to the sustainability of the global food system. Therefore, the main objective of this study is to identify a new distribution mode that can overcome the logistical barriers associated with surplus fresh food donations. This is especially crucial for fresh food, which has the highest nutritional value and taste immediately after harvesting but diminishes over time, leading to spoilage (Osvald & Stirn, 2008). Due to the perishability of these fresh foods and the need to maintain a cold chain to preserve their quality, they require particular attention in the distribution process (Pulina & Timpanaro, 2012). Ultimately, reducing food waste lies at the core of an effective food management system, necessitating the development of appropriate strategies for a sustainable food supply chain (Barlagne et al., 2015).

In contrast to many studies that utilize theoretical models such as delivery scheduling, routing, and location selection to address distribution mode issues (Gajanand & Narendran, 2013; Regazzoni et al., 2013; Ullrich, 2012; van den Heuvel et al., 2014), our research takes a different approach. We focus on understanding the behavioral preferences of key actors involved in fresh food donations, including farmers, the government, logistics service providers, and disadvantaged groups (DGs). By considering these preferences, our aim is to identify an appropriate distribution mode that minimizes overall distribution costs while ensuring the satisfaction of DGs with respect to fresh food donations. To achieve these objectives, this study employs TRIZ (Theory of Inventive Problem Solving) in conjunction with grey relational analysis. Through this approach, we develop preferred distribution modes that effectively distribute fresh food donations to DGs in a suitable manner. By integrating the insights gained from TRIZ and grey relational analysis, we can optimize the distribution process and enhance the overall effectiveness of fresh food donation initiatives.

In this article, an extensive literature review was conducted to examine the distribution modes of agricultural products, as well as TRIZ. Subsequently, TRIZ was applied to generate 11 feasible alternative distribution modes. Questionnaires were then administered to farmers, third-party logistics providers (3PLs), and disadvantaged groups (DGs) to determine the most appropriate options. Furthermore, the chosen distribution mode was tested through the presentation of relevant cases and examples. The analytical results and discussions derived from these investigations are presented, and concluding remarks are provided at the end of the article.

2 Distribution mode of agricultural products and TRIZ

2.1 Distribution performance of agricultural products

To assess the effectiveness of the agricultural distribution system, it is crucial to develop an appropriate performance measurement framework. Bowersox et al. (2000) and Gunasekaran et al. (2005) have incorporated performance metrics such as customer satisfaction, delivery speed, dependability, flexibility, and cost to evaluate distribution performance. However, with the growing emphasis on sustainable development and corporate social responsibility, there is a need to consider the social dimensions of logistics management and maximize both economic value and social expectations.

In this study, our specific goals are to achieve social welfare and address the social dimension, an aspect that has received limited attention from researchers (Beske-Janssen et al., 2015). To this end, we draw inspiration from the concept of humanitarian logistics performance, which aims to maximize the benefits of disadvantaged groups (DGs), farmers, and third-party logistics service providers (3PLs) by identifying an appropriate and cost-effective distribution approach for fresh food donations. To gain practical insights, we conducted

DOI: 10.6977/IJoSI.202406_8(2).0001
C. Wang, T. Lee, et al./Int. J. Systematic Innovation, 8(2),1-16 (2024)

in-depth interviews with industry experts, resulting in the identification of core criteria for fresh food distribution. Furthermore, building on the research conducted by Lan et al. (2008), which explored the distribution mode of regional food cold chains with a focus on improving economic and social effects, we identified safety, efficiency, and flexibility as the main influencing factors. By combining the insights from the in-depth interviews and existing literature, this study identifies three performance metrics: "freshness," "speed," and "convenience."

2.2 Government's current distribution options

Based on in-depth interviews conducted with the competent authority responsible for agricultural affairs in Taiwan, namely the Council of Agriculture (COA), six existing alternatives for distributing fresh food donations to disadvantaged groups (DGs) have been identified. These alternatives are outlined below:

#1. 3PL provides home delivery.
#2. Regional Governmental welfare institutes take care of distribution.
#3. Regional retailers' storage and DGs' pickup
#4. DGs bought from markets and got refund.
#5. The regional wholesalers purchased and distributed to DGs.
#6. Farmers distributed to DGs directly.

Based on the recommendations provided by experts, a comprehensive comparison was conducted to evaluate the six distribution options. The strengths and weaknesses of each option are summarized in Table 1.

Table 1. Comparisons of six options of distribution

Options	Strengths
#1	Quick response time, keep fresh
#2	Cheaper, known the locations of DGs
#3	Convenient Accessibility
#4	DGs got rights to buy what they need
#5	Cheap and sufficient storage space
#6	Low inventory costs
Options	**Weaknesses**
#1	Higher transportation costs
#2	Long response time
#3	Sometimes lack willingness to pickup
#4	Most DGs are short of cash
#5	Long response time and quantity variety
#6	Low Accessibility and quantity variety

After a thorough review and analysis of the distribution options, we assessed them based on the three-performance metrics: "freshness," "speed," and "convenience." As a result, we identified four viable distribution options (#1, 2, 3, and 4). Nevertheless, several barriers still hinder the distribution of fresh food donations, which will serve as catalysts for the creation of new innovative distribution modes, as discussed in the next section.

2.3 TRIZ

The Theory of Inventive Problem Solving (TRIZ) is a process that stimulates breakthrough thinking patterns and problem-solving approaches. TRIZ stands as a methodology and philosophy for the innovation and enhancement of systems across various domains, including science, education, business, industry, and services. It offers a systematic approach to solving problems and generating optimal solutions to even the most challenging issues (Bukhman, 2021). While originally developed for technical fields, TRIZ has increasingly been applied in non-technical sectors, including the service sector (Chai et al., 2005; Chen et al., 2015; Cong & Tong, 2008; Regazzoni et al., 2013; Retseptor, 2003). Zhang et al. (2003) suggested that the 40 Inventive Principles of TRIZ, commonly used for resolving contradiction problems, should be adapted for service operations instead of physical product development. Among the various tool sets of TRIZ, the 40 inventive principles (IPs) are particularly popular and frequently utilized (Cong & Tong, 2008). Jeeradist et al. (2016) applied TRIZ to improve passengers' perceptions of an airline's image by enhancing service quality and safety. Chen et al. (2015) mapped service-quality parameters with TRIZ parameters in the health sector, while Su and Lin (2008) proposed a creative and systematic model using TRIZ methodology for generating innovative solutions for quality improvement. TRIZ methodology is implemented in classroom teaching to transform the educational environment—converting silence into dynamic interaction, transforming the audience into active participants, turning passivity into active learning, and encouraging individual efforts to evolve into collaborative endeavors (Shouhui et al., 2022). In TRIZ methodology, most problems are accompanied by inherent contradictions, which can arise from conflicting requirements for the same element in the system or conflicting elements within the same system. Identifying these inherent contradictions is a crucial step in TRIZ problem analysis. Once a contradiction is formulated, more advanced TRIZ knowledge-based tools can be employed to resolve it. The resolution of the contradiction often leads to a solution for the main problem and other associated minor problems. The detailed contradiction matrix and corresponding principles can be found in Appendix I and II.

3 Develop innovative distribution options by TRIZ

Building upon the insights gathered from the in-depth interviews and existing methods of distributing fresh food donations to disadvantaged groups (DGs) in Taiwan, this study utilized TRIZ to generate innovative distribution options. By employing the TRIZ analysis process, we linked the identified strengths and weaknesses to the improving and worsening parameters in the TRIZ contradiction matrix. This enabled us to derive new innovative principles and corresponding distribution options. Based on the preliminary findings, four feasible distribution options (#1, 2, 3, and 4) were identified, and TRIZ was employed to analyze each of these options individually.

3.1 #1 3PL provides home delivery.

The identified strength of this distribution option lies in its quick response time, which helps maintain the freshness of the donations. This aligns with the TRIZ improving feature of "Adaptability or versatility (35)". Conversely, a weakness of this option is the higher transportation costs resulting from the dispersed locations of disadvantaged groups (DGs) and the need for disaggregated shipping. This corresponds to the TRIZ worsening feature of "loss of energy (22)". According to the TRIZ contradiction matrix, the inventive principles proposed to address the improving feature (35) and worsening feature (22) are "Mechanical Vibration (18)", "Dynamics (15)", and "Segmentation (1)".

3.1.1 Inventive Principles 18 “Mechanical Vibration”

Applying TRIZ inventive principle 18 to service industries, two relevant strategies are identified: "Benchmarking the best practices across different service industries to improve service quality and foster innovation in developing service offerings" and "Adapting service capacity based on the fluctuation pattern of customer demands." Building upon these principles, this study proposes a novel distribution option wherein the government collaborates with prominent convenience chain stores, specifically 7-Eleven. These stores possess inherent advantages in terms of accessibility and logistics expertise due to their extensive distribution network. Furthermore, they are committed to fulfilling their role as responsible and upright citizens by actively assisting disadvantaged groups (DGs) in need.

3.1.2 Inventive Principles 15 “Dynamics”

Applying TRIZ inventive principle 15 to service industries, two relevant strategies are identified: "Empowering frontline staff with discretionary authority in delivering services" and "Adapting service provisions to meet customer demands." Based on these principles, this study proposes that the government should establish an online exchange system to facilitate communication between farmers and DGs. Through this system, farmers can update information regarding their surplus fresh food, including type, quantity, and location. DGs, on the other hand, can place orders online and select their preferred delivery methods. By providing this platform, the government enables direct interaction between farmers and DGs, empowering them to make decisions and meet their specific needs.

3.1.3 Inventive Principles 1 “Segmentation”

Applying TRIZ inventive principle 1 to service industries, two relevant strategies are identified: "Dividing service packages into several components" and "Segmenting the customer base based on relevant information such as needs, ages, and buying behaviors." Based on these principles, this study proposes that the government should segment the areas where DGs are located based on population density. Subsequently, self-managed teams can be formed to oversee the calculation of demand information and explore suitable distribution options. By dividing the service packages into components and segmenting the customer base, the government can effectively tailor its distribution efforts to meet the specific needs of different areas and DGs.

3.2 #2 Regional Governmental welfare institutes take care of distribution.

The regional social welfare institutes possess strength in their deep understanding of DGs, leading to the corresponding TRIZ improving feature of "ease of operation (33)". However, a weakness is observed in the long response time due to the two-stage distribution process: collection from farmers, storage in warehouses, and subsequent delivery to DGs. This weakness aligns with the TRIZ worsening feature of "speed (9)". According to the TRIZ contradiction matrix, the proposed solutions for improving feature (33) and worsening feature (9) are the inventive principles of "Mechanical Vibration (18)", "The other way round (13)", and "Discarding and recovering (34)".

3.2.1 Inventive Principles 18 “Mechanical Vibration”

Applying inventive principles 18 to develop an innovative distribution option, we propose that the government should implement an appropriate incentive mechanism to reward the social workers of welfare institutes who are involved in the distribution of fresh food donations to DGs. By recognizing and rewarding their efforts, it will motivate and encourage them to perform their distribution tasks more effectively and efficiently.

3.2.2 Inventive principles 13 “The other way round”

Applying inventive principles 13 to service industries, we can consider the following approaches: "Invert the action(s) used to solve the problem, e.g. e-services," "make fixed parts movable, e.g. delivering on-site services," and "turn the object upside down, e.g. customers can serve themselves." Correspondingly, we propose that the government should reorganize the inbound and outbound logistics processes. The collection of fresh food donations can be assigned to the government to achieve economies of scale, while the small-batch last-mile delivery can be outsourced to third-party logistics providers (3PLs). By dividing the tasks, both the government and 3PLs can benefit from the division of labor, resulting in more efficient and effective distribution of fresh food donations to DGs.

3.2.3 Inventive Principles 34 “Discarding and recovering.”

Applying inventive principle 34 to service industries, which suggests removing and reusing elements directly after they have fulfilled their functions, we propose that the government should consider signing long-term outsourcing contracts with third-party logistics providers (3PLs) instead of engaging in arms-length market transactions. By establishing long-term partnerships with trusted 3PLs, the government can cultivate relational capital among themselves, the 3PLs, and the DGs. This approach aims to enhance collaboration and cooperation, ultimately increasing the overall social welfare in the distribution of fresh food donations.

3.3 #3 The Regional Retail Storage and DGs pickup

The distribution option's strength lies in its convenient accessibility due to the widespread presence of retail stores in Taiwan. This aligns with the TRIZ improving feature of "ease of operation (33)". However, a weakness of this option is the potential decrease in willingness to pick up fresh food donations when the price of the food decreases. This corresponds to the TRIZ worsening feature of "stability of the object (13)". The contradiction matrix suggests employing inventive principles such as "Color changes (32)", "Parameter changes (35)", and "Flexible shells and thin films (30)" to address these contradictions.

3.3.1 Inventive Principles 32 “Color changes”

Principles 32, when applied to service industries, encompass offering different options for delivering the service to add value to the customer and utilizing color change to enhance transparency and trust. Building upon these principles, we propose that the government should establish a dedicated and transparent communication platform. This platform will serve to disclose relevant information to all stakeholders who willingly participate in the distribution of fresh food donations to the intended beneficiaries. The application of inventive principles 35 will be further discussed in section 3.4.2.

3.3.2 Inventive Principles 30 “Flexible

shells and thin films"

Principles 30, when applied to service industries, focus on isolating functions, processes, and activities to reduce costs. Drawing from this principle, we propose the separation of two types of beneficiary groups (DGs). DGs residing near the farmers' fields should be responsible for self-pickup, while those located far away should rely on third-party logistics providers (3PLs) for delivery. By implementing this approach, the overall distribution costs can be optimized and reduced.

3.4 #4 DGs bought from markets and got refund.

The strength of this distribution option is DGs have more choices to buy what kind of fresh food they need and increase their willingness to participate, and then the corresponding TRIZ improving features is "power (21)". The weakness is the complicated and time-consuming process to get a refund, also has liquidity problem of cash flow for DGs, and the corresponding TRIZ worsening features is "difficulty of detecting and measuring (37)". The contradiction matrix shows the proposed solutions are inventive principles "periodic action (19)", "Parameter changes (35)", and "Partial or excessive actions (16)".

3.4.1 Inventive principles 19 "periodic action"

Principles 19 applied to service industries emphasizes the importance of collecting customers' feedback regularly, providing specific services periodically, and engaging in repeated promotion activities. In line with these principles, we propose that governmental authorities should regularly collect information on DGs' demand quantity and offer home delivery services to meet their specific needs.

3.4.2 Inventive principles 35 "Parameter changes"

Principles 35 applied to service industries highlights the importance of simplifying the service process and upgrading services for loyal customers. These principles emphasize the need for change. In line with these principles, we propose a change in the delivery responsibilities from the government to farmers. The government can prioritize those farmers who provide voluntary logistics services in purchasing contracts. This change aims to streamline the delivery process and provide enhanced services for loyal customers.

3.4.3 Inventive principles 16 "Partial or excessive actions"

Principles 16 applied to service industries emphasize the importance of providing beforehand notices and explanations to customers regarding the temporary unavailability of services. This helps prevent a loss of customer loyalty due to blind waiting. Additionally, satisfying customers with high service quality is crucial. In line with these principles, we propose that the government invite 3PLs that prioritize their social responsibility and aim to enhance their corporate image through offering distribution services. The government can provide preferential subsidies or tax reductions to partially cover the logistics costs incurred by these 3PLs. This approach encourages the involvement of socially responsible 3PLs and ensures the provision of high-quality distribution services.

4 Use TRIZ to develop new distribution options.

We have employed the inventive thinking approach of the TRIZ methodology to develop a systematic framework that showcases new distribution options for fresh food donations. The main innovative options are summarized as follows:

a. Utilizing demand information requested in advance by DGs to determine the timing and method of distribution.
b. Prioritizing the purchase of donations from farmers willing to undertake distribution to neighboring DGs.
c. Inviting socially responsible 3PLs that emphasize their corporate image enhancement through distribution services, while offering preferential government subsidies or tax reductions to partially cover their logistics costs.
d. Collaborating with leading convenience chain stores such as 7-ELEVEN, which possess accessibility advantages and logistics expertise due to their extensive distribution network. These stores are fully committed to serving as

responsible and upright citizens, assisting DGs.

e. Establishing an online exchange system to bridge the gap between farmers and DGs. Through this system, farmers can update information on fresh food over-supply (type, quantity, location, etc.), while DGs can place online orders and select their preferred delivery methods.
f. Segmenting DGs based on population density and forming self-managed teams responsible for managing demand information and distribution options.
g. Rewarding social workers from regional governments who distribute surplus agricultural products to DGs and receive positive feedback.
h. Undertaking inbound logistics while outsourcing the last mile delivery to 3PLs, allowing for a division of labor that benefits both governments and 3PLs.
i. Signing long-term outsourcing contracts with 3PLs to cultivate relational capital among the government, 3PLs, and DGs, thereby increasing overall social welfare.
j. Establishing a specific and transparent communication platform to disclose related information to all stakeholders voluntarily participating in the distribution of fresh food donations to DGs.
k. Implementing a separation strategy for two types of DGs: those residing near farmers' fields can pick up the donations themselves, while others living farther away rely on 3PLs for delivery, resulting in improved overall distribution costs.

In addition, three major goals have been identified for the distribution of fresh food donations: "freshness," "speed," and "convenience." We conducted questionnaires to gather opinions from relevant professionals, including logistics service providers and governmental officials responsible for fresh food donations. The results of the survey will assist in selecting the most appropriate distribution modes to achieve the specified goals.

5 Grey relational analysis

By integrating existing literature, governmental information, and interviews with industry experts, this study has identified three main distribution goals for distributing fresh food donations to DGs. Additionally, this study has developed eleven new distribution options using the TRIZ methodology. Subsequently, questionnaires were administered to gather data from governments, farmers, and DGs to align the new distribution options with the three established goals. The results of the collected questionnaires are presented below and are divided into four sections, which describe the survey results, define the research targets, outline the questionnaire design, present the analysis method, and discuss the empirical results.

5.1 Define the search targets.

The objective of this questionnaire is to identify the most suitable method for distributing fresh food donations to DGs. Therefore, the questionnaire was primarily distributed to three target groups: DGs, farmers, and 3PLs.

5.2 Questionnaire Design

The questionnaire is structured into five parts. Part 1 focuses on the weighted priority of distribution options, while parts 2 to 4 address the goals of freshness, speed, and convenience, respectively, followed by the weighted priority of distribution options for each goal. Part 5 collects demographic information from respondents.

5.3 Research Methods

For data analysis, this study employed the grey relational analysis (GRA) method. The GRA method calculates the correlation degree of each evaluation object to estimate its grade. It combines qualitative and quantitative analysis and overcomes the limitations of traditional correlation analysis methods, which are not suitable for nonlinear models. The fundamental idea of GRA is to assess the similarity level of geometric patterns of sequence curves and determine the closeness to system characteristics based on relevant factors. Assume that $X_0 = (x_0(1), x_0(2), \dots, x_0(n))$ represents the sequence of data representing the system characteristics, and $X_i = (x_i(1), x_i(2), \dots, x_i(n))$, $i = 1, 2, \dots, m$ represents sequences of m relevant factors. The degree of grey incidence (or grey rational grade) for X_i with respect to X_0, $_{0i} = (X_0, X_i)$, is defined by Equations (1) and (2), where $_{0i}(k)$ is the incident coefficient of k^th sample between sequences X_0 and X_i and a distinguishing coefficient which value is between 0 and 1, as a lot of contribution, this study set distinguishing coefficient (ζ) as 0.5 to enlarge the difference among final incident coefficients, and then calculated to get the grey relational coefficient.

$$\gamma_{oi} = \gamma(X_0, X_i) = \frac{1}{n}\sum_{k=1}^{n}\gamma_{oi}(k), i = 1,2,\dots,m \quad (1)$$

The procedures of GRA are, (1) list the comparative series for further investigation (2) calculate the distance between comparative and reference series (3) calculate the grey relational coefficient (4) determine the grade of grey relations (5) depict the chart based on grey relational grade (GRG).

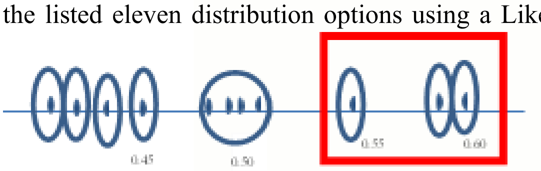
In this study, we present the GRG in a graphical format. Each point on the lines represents a value calculated by grey relational analysis, where a higher value indicates a greater importance of the corresponding options. The points are grouped based on the tightness of each value. The critical success factors (CSFs) suggest that in any organization, certain factors (typically three to six factors) are critical to its success. This study will retain less than half of the options in the questionnaire, which is less than 11/2≒5.

5.4 Empirical results

In our study, we distributed the questionnaires to three groups: DGs, farmers, and 3PLs, and received valid samples from 198 DGs, 6 farmers, and 5 3PLs. Using grey relational analysis, and considering the four expected goals, namely "Ranks of favorite distribution options", "Freshness", "Speed", and "Convenience", we present the ranks of distribution options as follows.

5.4.1 Ranks of favorite distribution options

In this question, respondents were asked to score the listed eleven distribution options using a Likert 5-



point scale. From the perspective of DGs, we identified three Critical Success Factors (CSFs): “b. (GRG=0.593)”, “a. (GRG=0.576)”, and “c. (GRG=0.539)”, as shown in **Figure 1**.

Figure 1. Ranks of favorite distribution options with GRG-the perspectives of DGs (note：Points located in red rectangle mean CSFs)

From the perspectives of farmers, we extracted four CSFs, that is “j. (GRG=1)”, “c. (GRG=0.792)”, “f. (GRG=0.782)”, “b.(GRG=0.735)”. As to the perspectives of 3PLs, we extracted three CSFs, that is “k. (GRG=1)”, “b. (GRG=0.8222)”, and “f. (GRG=0.7556) shown in **Figure 2** and **Figure 3**.

Figure 2. Ranks of favorite distribution options with GRG-the perspectives of farmers

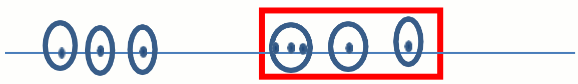
Figure 3 Ranks of favorite distribution options with GRG-the perspectives of 3PLs

In summary, this study identified that "b. If the farmers are willing to undertake distribution of donations to neighboring DGs, the government will give priority to purchase from these farmers" is the only option that was considered a priority by all three groups (DGs, farmers, and 3PLs). Option "c." received support from both DGs and farmers, while option "f." was identified as preferred by farmers and 3PLs. These results indicate differences in preference among the three groups.

5.4.2 Freshness

Given the goal of keeping freshness, and from the perspectives of DGs who extracted five CSFs that is “b. (GRG=0.586)”, “a. (GRG=0.547)”, d. (GRG=0.51)”, “f. (GRG=0.508)”, “c. (GRG=0.502)”.

Famers identified four CSFs that are “a. (GRG=1)”, “j. (GRG=0.815)”, “f. (GRG=0.759)”, and “h. (GRG=0.754).” 3PLs have identified four CSFs that is “b. (GRG=0.822)”, “k. (GRG=0.810)”, “ i. (GRG=0.698)”, “h. (GRG=0.676). Shown in **Figures 4**, 5, and 6 respectively.



DOI: 10.6977/IJoSI.202406_8(2).0001
C. Wang, T. Lee, et al./Int. J. Systematic Innovation, 8(2),1-16 (2024)

Figure 4. Ranks of priority distribution options with GRG given the goal of keeping freshness -the perspectives of DGs

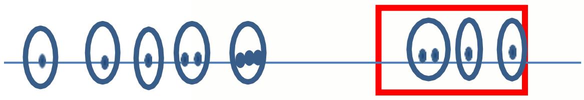


Figure 5. Ranks of priority distribution options with GRG given the goal freshness -the perspectives of farmers.

Figure 6. Ranks of priority distribution options with GRG given the goal of keeping freshness -the perspectives of 3PLs

According to the results, both DGs and farmers reach mutual agree in "a" and "f". And b got support from both DGs and 3PLs. As to supporting by farmers and 3PLs is "j."

5.4.3 Speed

Given the goal of speed, and from the perspectives of DGs who extracted three CSFs that is "b (GRG=0.585)", "c (GRG=0.535)", and "d (GRG=0.532)". The farmers identified three CSFs that is "a (GRG=1)", "j (GRG=0.815), and "i (GRG=0.75)". The 3PLs identified four CSFs that is " a (GRG=0.440)", "b (GRG=0.350)", "h(GRG=0.263)", and "e (GRG=0.204). Shown in figure 7, 8 and 9 respectively.

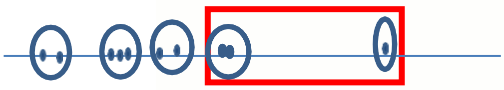


Figure 7. Ranks of priority distribution options with GRG given the goal of speed-the perspectives of DGs

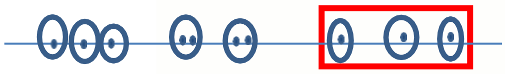


Figure 8. Ranks of priority distribution options with GRG given the goal of speed-the perspectives of farmers

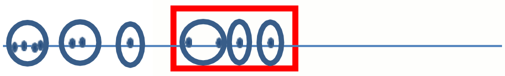


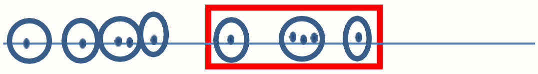
Figure 9. Ranks of priority distribution options with GRG given the goal of speed-the perspectives of 3PLs

According to the results and given the goal of speed, both DGs and 3PLs agree "b" is the priority distribution option. Farmers and 3PLs reached a mutual agreement in "a."

5.4.4 Convenience

Given the goal of convenience, and from the perspectives of DGs who extracted five CSFs that is "b (GRG=0.564)", "c (GRG=0.526)", "d (GRG=0.521)", "a (GRG=0.516)", and "i (GRG=0.503).

Farmers identified four CSFs that is "a (GRG=0.778)", "(GRG=0.815)", "i (GRG=0.754)", and "f (GRG=0.73)." The 3PLs identified four CSFs that is "a (GRG=0.613)", "d (GRG=0.421)", "g (GRG=0.297)", and "k (GRG=0.256)." Shown in Figures 10, 11, and 12



respectively.

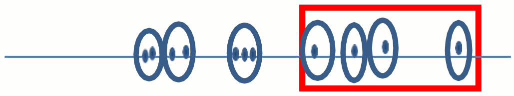


Figure 10. Ranks of priority distribution options with GRG given the goal of convenience-the perspectives of DGs

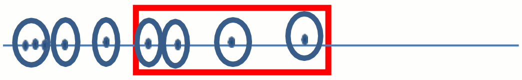


Figure 11. Ranks of priority distribution options with GRG given the goal of convenience-the perspectives of farmers

Figure 12. Ranks of priority distribution options with GRG given the goal of convenience-the perspectives of 3PLs

Based on the obtained results and with a focus on the goal of convenience, this study observed that option "a" was identified as a priority by all three groups. Additionally, both DGs and 3PLs considered option "d" as a priority. To facilitate comparisons, Table 2 presents a summary of the rankings of distribution options as perceived by DGs, farmers, and 3PLs, considering different goals.

Table 2. Summaries of ranks (DGs, farmers, and 3PLs)

Ranks of favorite distribution options		
DGs	Farmers	3PL
b.(.5932)	j. (1)	k.(1.)
a.(.5756)	c. (.792)	b.(.8222)
c.(.5386)	f. (.782)	f.(.7556)

	b. (.735)	
Freshness		
DGs	Farmers	3PL
b. (.586)	a. (1)	b.(.822)
a. (.547)	j. (.815)	k.(.810)
d. (.51)	f. (.759)	i.(.698)
f. (.508)	h. (.754)	j.(.676)
c. (0.502)		
Speed		
DGs	Farmers	3PL
b. (0.585)	a.(1)	a. (0.440)
c. (0.535)	j.(0.815)	b. (0.350)
d. (0.532)	i.(0.75)	h. (0.263)
		e. (0.204)
Convenience		
DGs	Farmers	3PL
b. (0.564)	a. (0.778)	a.(0.613)
c. (0.526)	j. (0.815)	d.(0.421)
d. (0.521)	i. (0.754)	g.(0.297)
a. (0.516)	f. (0.73)	k.(0.256)
i. (0.503)		

Note: a b, c…k stands for eleven distribution options

According to the findings presented in Table 2, DGs regarded option "b" as the preferred distribution option. Farmers, on the other hand, identified option "j" as the best, while 3PLs considered option "k" as their priority choice. When considering the goal of maintaining freshness, DGs prioritized option "b", whereas farmers favored option "a", and 3PLs also considered option "b" as their top choice. In terms of speed, DGs considered option "b" as the priority option, while both farmers and 3PLs believed option "a" to be the preferred distribution method. Similarly, for the goal of convenience, the priority options align with those for speed.

Based on these results, several common elements were identified that were highlighted by all three groups (DGs, farmers, and 3PLs). Firstly, obtaining advance demand information from DGs was deemed crucial as it allows for efficient planning of delivery routes and quantities, reducing unnecessary distribution arrangements, and taking advantage of economies of scale. Transparency in demand information contributes to increased distribution efficiency. Secondly, "home delivery" emerged as the most preferred distribution mode by all three groups. However, there were differences in perceptions regarding who should bear the transportation costs associated with home delivery. While all three groups recognized the benefits of "home delivery" in achieving freshness, speed, and convenience, the issue of cost responsibility remains controversial and unresolved.

In conclusion, this study suggests that "home delivery" is the appropriate distribution mode. However, the issue of cost sharing for home delivery remains a contentious and unresolved matter.

6 Case study

`To illustrate distribution efficiency, a case study was conducted. The study consists of three parts: investigating the numbers and demand information of DGs, presenting the contents and estimated costs of alternative distribution options, and evaluating the performance of these options.

6.1 Numbers and demand information of DGs

Government authorities investigated and identified 391 DGs in need of fresh fruit donations, with a total of 35,014 individuals. Among these DGs, 179 groups (17,472 people) purchased the fruits themselves and received refunds from the government, while the remaining 212 groups (17,542 people) relied on home delivery. The total distribution weight amounted to 18,400 kilograms (kg).

6.2 Contents and estimated costs of alternatives

In this section, we demonstrate two distribution options proposed by the Taiwan Government: option 1, where DGs purchase the fruits themselves and opt for home delivery, and option 2, where Kerry Logistics offers free distribution services. The total expenditures for option 1 and option 2 are estimated to be approximately USD 15,672 and USD 12,294, respectively. The details are as follows:

6.2.1 Option1: DGs purchased by themselves and home delivery

1. **DGs purchases**
   a. To simplify implementation procedures and ensure price consistency, the Government announced a reference price range of USD 0.83 to 1 per kilogram (kg) based on surveys conducted at Taipei's fruits and vegetables markets. The subsidy standard was set at USD 1 per kg.
   b. Government authorities notified DGs through official documents that they had 7 days to purchase the specified quantities of guava from the nearest supermarkets or agricultural stores. The stores would then issue invoices or receipts. DGs were required to send back these invoices/receipts along with their bank account numbers to the government authorities to obtain reimbursement for their expenditures.

Table 3 provides a detailed breakdown of the purchases made by 179 groups (17,472 people) who bought the fruits themselves and submitted their invoices to the government authorities. Each person received 0.5 kg (9,140 kg in total) of guava, with a subsidy of USD 1 per kg plus transfer fees. The total expenditures for this option amounted to approximately USD 9,319.

Table 3. Expenditures of DGs purchased by themselves

Total Demand	9,140 Kilogram (457catons, CTNs)
expenditures	Guava price USD 9,140 (457CTNs*20kg*USD 1=9,140)
	Transferring fees 179 (179 units*USD 1=179)
	Total 9,319

2. **Home delivery**
   a. Kerry Logistics provided free distribution services.
   b. The government set the reference price for purchasing guavas from farmers at USD 0.57. As a result, 212 DGs required a total of 9,260 kg of donated guavas. The logistics operation cost was estimated to be USD 0.067 per kg, and the labeling fee was USD 0.034 per unit. The total expenditures for this option were approximately USD 6,019, as presented in Table 4.

Table 4. Expenditures of Home delivery by Kerry Logistics

Total Demand	9,260 Kilogram (463 CTNs)
Expenditures	Guava price USD 5,279 (463 CTNs*20kg*USD 0.57=5,279)
	Operation Cost 620 (9,260kg* USD 0.066= USD 620)
	Labeling 157.4 (463CTNs* USD 0.34=USD 157)
	Total 6,056

Total expenditures of DGs purchased and home delivery is USD 15,194.

6.2.2. Option 2: Kerry Logistics offered free distribution services.

The government announced the reference price for purchasing guavas from farmers to be USD 0.57. There is a total of 391 DGs (consisting of 35,014 people) in need of donated guavas. The logistics operation cost is estimated to be USD 0.067 per kg, and the labeling fee is USD 0.034 per unit. The total expenditures for this option are approximately USD 12,034, as presented in Table 5.

Table 5. Kerry Logistics offered free distribution services.

Total Demand	18,400 Kilogram (920 CTNs)
Expenditures	Guava price USD 10,448 (920 CTNs*20kg*USD 0.57=10,488)
	Operation Cost 1,233 (18,400kg* USD 0.067= USD 1,233)
	Labeling 313 (920 CTNs* USD 0.034=USD 313)
	Total 12,034

Compared these two options, total expenditures are USD 15,194 and 12,034 for options 1 and 2 respectively, the winner is option 2, and the gap (cost saving) is USD 3,160.

7 Discussion

The findings of this study accentuate the critical role of advanced demand information in optimizing the distribution of food donations. The unanimous endorsement from DGs, farmers, and 3PLs regarding the necessity for transparency in demand data underscores its importance in streamlining delivery routes and quantities, which potentially mitigates superfluous logistics efforts and leverages economies of scale. Home delivery, favored across all parties, emerges as a significant advancement in the distribution model, addressing key performance metrics of freshness, speed, and convenience. Yet, the persisting debate over fiscal responsibilities linked to transportation costs for home delivery indicates a need for a consensus-driven model to address cost-sharing mechanisms.

The preference for home delivery further signifies a paradigm shift in distribution towards more consumer-centric approaches that value direct and rapid access to goods. However, the divergent views on cost assumption highlight the complexities inherent in implementing such systems, where the benefits of efficiency and immediacy must be balanced against the economic viability and sustainability of the distribution network. This study contributes to this discourse by suggesting that the resolution of this contention is pivotal for the successful adoption of home delivery as the preferred mode of distribution.

8 Conclusion

This investigation set out to forge an innovative distribution model capable of enhancing social welfare while concurrently minimizing food waste, aligning with the United Nations' Sustainable Development Goal 12. The rigorous process of literature review, expert interviews, and integration of governmental measures culminated in the identification of three salient performance metrics and the development of eleven distribution alternatives via TRIZ methodology. The empirical assessment, including a real-data test, established a distribution framework that notably prioritizes government incentivization of 3PL voluntary services, supported by subsidies or tax incentives.

The advocated model not only fosters economic efficiency by reducing distribution costs but also endorses a socially responsible corporate ethos among 3PLs, potentially elevating their public image. The government's pivotal role extends beyond facilitation to regulation and oversight of the logistical and financial flows of food donations, where strategic partnerships with financial institutions can streamline subsidy and payment processes. The establishment of an online platform for the real-time disclosure of donation information is proposed as an essential component of this model, ensuring that DGs can seamlessly access donation data, and 3PLs can execute logistics tasks with enhanced precision.

Encouraging 3PL participation through sufficient incentives and societal advocacy for corporate social responsibility represents a holistic approach that integrates the strengths of public, private, and social sectors. This study underscores the significance of such collaborative efforts in reinforcing the sustainable management of food surplus and the realization of distribution models that are both efficient and equitable. The successful implementation of these recommendations is anticipated to have a positive impact on the reduction of food waste, fostering a more sustainable and responsible food distribution ecosystem.

References

Abbade, E. B. (2020). Estimating the nutritional loss and the feeding potential derived from food losses worldwide. World development, 134, 105038. https://doi.org/https://doi.org/10.1016/j.worlddev.2020.105038

Aysoy, C., Kirli, D. H., & Tumen, S. (2015). How does a shorter supply chain affect pricing of fresh food? Evidence from a natural experiment. Food Policy, 57, 104-113. https://doi.org/10.1016/j.foodpol.2015.10.003

Barlagne, C., Bazoche, P., Thomas, A., Ozier-Lafontaine, H., Causeret, F., & Blazy, J.-M. (2015). Promoting local foods in small island states: The role of information policies. Food Policy, 57, 62-72. https://doi.org/https://doi.org/10.1016/j.foodpol.2015.09.003

Beske-Janssen, P., Johnson, M. P., & Schaltegger, S. (2015). 20 years of performance measurement in sustainable supply chain management – what has been achieved? Supply Chain Management: An International Journal, 20(6), 664-680. https://doi.org/10.1108/scm-06-2015-0216

Bowersox, D. J., Closs, D. J., & Stank, T. P. (2000). Ten mega-trends that will revolutionize supply chain logistics. Journal of Business Logistics, 21(2), 1-16. https://www.proquest.com/scholarly-journals/ten-mega-trends-that-will-revolutionize-supply/docview/212591409/se-2?accountid=12469 http://pqdd.sinica.edu.tw/twdaoapp/servlet/advanced?query=

Bukhman, I. (2021). The Ideas of TRIZ. In I. Bukhman (Ed.), Technology for Innovation: How to Create New Systems, Develop Existing Systems and Solve Related Problems (pp. 1-9). Springer Singapore. https://doi.org/10.1007/978-981-16-1041-7_1

Chai, K.-H., Zhang, J., & Kay-Chuan, T. (2005). A TRIZ-Based Method for New Service Design. Journal of Service Research: JSR, 8(1), 48-66. https://www.proquest.com/scholarly-journals/triz-based-method-new-service-design/docview/210509481/se-2?accountid=12469 http://pqdd.sinica.edu.tw/twdaoapp/servlet/advanced?query=

Chen, C.-K., Shie, A.-J., Wang, K.-M., & Yu, C.-H. (2015). An Ageing-in-Place Service Innovation Model by Using TRIZ Methodology. Human Factors and Ergonomics in Manufacturing & Service Industries, 25(2), 166-182. https://doi.org/https://doi.org/10.1002/hfm.20536

Cong, H., & Tong, L. H. (2008). Grouping of TRIZ Inventive Principles to facilitate automatic patent classification. Expert Systems with Applications, 34(1), 788-795. https://doi.org/https://doi.org/10.1016/j.eswa.2006.10.015

De Hooge, I. E., Oostindjer, M., Aschemann-Witzel, J., Normann, A., Loose, S. M., & Almli, V. L. (2017). This apple is too ugly for me!: Consumer preferences for suboptimal food products in the supermarket and at home. Food Quality and Preference, 56, 80-92. https://doi.org/https://doi.org/10.1016/j.foodqual.2016.09.012

Gajanand, M. S., & Narendran, T. T. (2013). Green route planning to reduce the environmental impact of distribution. International Journal of Logistics Research and Applications, 16(5), 410-432. https://doi.org/10.1080/13675567.2013.831400

Garrone, P., Melacini, M., & Perego, A. (2014). Opening the black box of food waste reduction. Food Policy, 46, 129-139. https://doi.org/https://doi.org/10.1016/j.foodpol.2014.03.014

Gunasekaran, A., Williams, H. J., & McGaughey, R. E. (2005). Performance measurement and costing system in new enterprise. Technovation, 25(5), 523-533. https://doi.org/https://doi.org/10.1016/j.technovation.2003.09.010

Jeeradist, T., Thawesaengskulthai, N., & Sangsuwan, T. (2016). Using TRIZ to enhance passengers' perceptions of an airline's image through service quality and safety. Journal of Air Transport Management, 53, 131-139. https://doi.org/https://doi.org/10.1016/j.jairtraman.2016.02.011

Lan, H., Guo, L., & Sun, M. (2008). Study on the distribution modes selection of the regional food cold chain. 2008 IEEE International Conference on Service Operations and Logistics, and Informatics,

Mokrane, S., Buonocore, E., Capone, R., & Franzese, P. P. (2023). Exploring the Global Scientific Literature on Food Waste and Loss. Sustainability, 15(6). https://doi.org/10.3390/su15064757

Osvald, A., & Stirn, L. Z. (2008). A vehicle routing algorithm for the distribution of fresh vegetables and similar perishable food. Journal of Food Engineering, 85(2), 285-295. https://doi.org/https://doi.org/10.1016/j.jfoodeng.2007.07.008

Pulina, P., & Timpanaro, G. (2012). Ethics, sustainability and logistics in agricultural and agri-food economics research. Italian Journal of Agronomy, 7(3), e33-e33.

Regazzoni, D., Pezzotta, G., Persico, S., Cavalieri, S., & Rizzi, C. (2013, 2013//). Integration of TRIZ Problem Solving Tools in a Product-Service Engineering Process. The Philosopher's Stone for Sustainability, Berlin, Heidelberg.

Retseptor, G. (2003). 40 inventive principles in quality management. The TRIZ Journal, 1, 25.

Schanes, K., Dobernig, K., & Gözet, B. (2018). Food waste matters - A systematic review of household food waste practices and their policy implications. Journal of Cleaner Production, 182, 978-991. https://doi.org/https://doi.org/10.1016/j.jclepro.2018.02.030

Secondi, L., Principato, L., & Laureti, T. (2015). Household food waste behaviour in EU-27 countries: A multilevel analysis. Food Policy, 56, 25-40. https://doi.org/https://doi.org/10.1016/j.foodpol.2015.07.007

Seminar, K. B. (2016). Food Chain Transparency for Food Loss and Waste Surveillance. Journal of Developments in Sustainable Agriculture, 11(1), 17-22. https://doi.org/10.11178/jdsa.11.17

Shouhui, C., Jing, H., Shaopei, J., Wenli, Z., Zhongjie, Z., Jin, Z., & Huijun, Z. (2022). Classroom Teaching Design Based on TRIZ Inventive Principles. The Theory and Practice of Innovation and Enntrepreneurship, 5(21), 150-152. http://www.cxcybjb.com/EN/abstract/article_4919.shtml

Shukla, M., & Jharkharia, S. (2013). Agri-fresh produce supply chain management: a state-of-the-art literature review. International Journal of Operations & Production Management, 33(2), 114-158.

Ullrich, C. A. (2012). Supply chain scheduling: makespan reduction potential. International Journal of Logistics Research and Applications, 15(5), 323-336. https://doi.org/10.1080/13675567.2012.742045

Van den Heuvel, F. P., de Langen, P. W., van Donselaar, K. H., & Fransoo, J. C. (2014). Proximity matters: synergies through co-location of logistics establishments. International Journal of Logistics Research and Applications, 17(5), 377-395. https://doi.org/10.1080/13675567.2013.870141

Van Giesen, R. I., & de Hooge, I. E. (2019). Too ugly, but I love its shape: Reducing food waste of suboptimal products with authenticity (and sustainability) positioning. Food Quality and Preference, 75, 249-259. https://doi.org/https://doi.org/10.1016/j.foodqual.2019.02.020

Zhang, J., Tan, K.-C., & Chai, K.-H. (2003). Systematic innovation in service design through TRIZ. The TRIZ Journal, 9(1), 1013-1022.

AUTHOR BIOGRAPHIES

Chih Yung Wang is an Associate Professor at the department of business administration at Ming Chuan University. He received his Ph.D. degree and MBA degree from the Department of Business Administration at National Sun-Yat-Sen University. His areas of interest include Fintech, Corporate governance, Financial Analysis, and Sports Management.

Tzong-Ru (Jiun-Shen) Lee Dr. Tzong-Ru Lee is a professor at the Department of Marketing, National Chung Hsing University, Taiwan R.O.C. His research interests include sustainability, carbon business model, supply chain, agriculture innovation, internet marketing and e-commerce, logistics, technology and innovation, etc.. He serves as International Committee General Convener of CIBED, Fullbright Visiting Professor to USA, Fellow of IAAS, international adviser for Small Businesses of EBRD, and conference lecturer of Asia-Pacific Economic Cooperation (APEC). He has published 6 books and around 200 articles in domestic and international journals. He also is the ceditor-in-chief of IJAITG.

Ville Isoherranen is the acting President and CEO of Vaasa University of Applied Sciences (VAMK), Vaasa, Finland, Vice President at VAMK, and Director of School of Technology at VAMK. Dr. Isoherranen is also Adjunct Professor at the Faculty of Technology, Industrial Engineering and Management at the University of Oulu, Oulu, Finland. Dr. Isoherranen's research interests are strategic management, operational excellence and knowledge-based management. Dr. Isoherranen has extensive international experience from leadership positions from several business functions both from global corporations and from technology start-ups, he has led multidisciplinary research groups and unit organizations at Universities and Higher Education institutions as well as driven corporate wide strategic change initiatives for business growth and renewal.

Shiou-Yu Chen is currently a professor in the Department of Shipping and Transportation Management at the National Taiwan Ocean University. She received a Ph.D. in International Business studies at National Taiwan University, majoring in International Business Management and minoring in Strategic Management. Her research interests primarily lie in organization and business management, supply chain management, and shipping and port management. She frequently publishes her research in international journals and presents at international conferences. Currently, she serves on the editorial board of the 'Journal of International Business and System Studies' and acts as a reviewer for multiple international and domestic journals (such as Tourism Management, IJPE, IJLM, IJBSR, BIT, and the Transportation Planning Quarterly). She also continues to offer services to government agencies and businesses, such as assisting the Taiwan International Port Corporations in promoting marketing projects, making long-term strategic plans, conducting market research, and providing on-job training etc. Additionally, she serves as a reviewer for the Ministry of Transportation's Institute of Transportation and the Bureau of Harbors. Practically, she has also participated in international competitions and currently holds two patents for innovative services at container ports.

DOI: 10.6977/IJoSI.202406_8(2).0001
C. Wang, T. Lee, et al./Int. J. Systematic Innovation, 8(2),1-16 (2024)

Appendix I the contradiction matrix

Deteriorated Attributes Improved Attributes	Weight of moving object	Weight of stationary object	Length of moving object	Length of stationary object	Area of moving object	…	Productivity
Weight of moving object			15,8, 29,34		29,1, 38,34	…	35,3 24,37
Weight of stationary object				10,1 29,35		…	1,28 15,35
Length of moving object	8,15, 29,34					…	14,4 28,29
Length of stationary object		35,2 40,29				…	30,1 7,26
Area of moving object	2,17, 29,4		14,15 16,4			…	10,2 34,2
…..	…	…	…	…	…	…	…
Productivity	35,2, 24,37	28,2, 15,3	18,4, 28,38	30,7, 14,26	10,2, 34,3	…	

Appendix II the 40 inventive principles

No	Principle	No	Principle	No	Principle
1	Segmentation	15	Dynamics	28	Mechanics substitution
2	Taking out	16	Partial or excessive action	29	Pneumatics and hydraulics
3	Local quality	17	Another dimension	30	Flexible shells and thin films
4	Asymmetry	18	Mechanical vibration	31	Porous materials
5	Merge	19	Periodic action	32	Color changes
6	Universality	20	Continuity of useful action	33	Homogeneity
7	Nesting	21	Skipping	34	Discarding and recovering
8	Anti-weight	22	Blessing in disguise	35	Parameter change
9	Preliminary anti-action	23	Feedback	36	Phase transition
10	Preliminary action	24	Intermediary	37	Thermal expansion
11	Beforehand cushioning	25	Self-service	38	Boosted interactions
12	Equipotentiality	26	Copying	39	Insert atmosphere
13	Inverse	27	Cheap short-living objects	40	Composite structure
14	Spheroidality				

DOI: 10.6977/IJoSI.202406_8(2).0002
S. D. Thepade, P. M. Pardhi. /Int. J. Systematic Innovation, 8(2), 17-30 (2024)

Enhancing visibility of nighttime images using wavelet decomposition with Kekre's LUV color space

Sudeep D. Thepade[1], Pravin M. Pardhi [2]*

[1] Professor, Computer Engineering Dept, PCCOE, Pune, 411044, India

[2] Department Research Scholar, Department of Technology, SPPU, Pune, 411007, India

* Corresponding author E-mail: pardhipravin44@gmail.com

(Received 11 July 2023; Final version received 13 March 2024; Accepted 19 March 2024)

Abstract

Contrast enhancement is a crucial preprocessing method for enhancing the efficiency of subsequent image processing and computer vision tasks. In the past, a lot of effort has been put into improving the visual scenes of pictures taken in low light. Images taken in poor illumination environments frequently reveal issues like color distortion, noise, low brightness, etc., that negatively impact the visual influence on human eyes. Therefore, an approach for improving poorly illuminated images based on wavelet transform is suggested to get around this problem. The input image is first transformed to Kekre's LUV color space, after which discrete wavelet transform (DWT) is applied to part each channel into low and high-frequency components. As the illumination is concentrated on the low-frequency image component, the Exposure-based Sub Image Histogram Equalization (ESIHE) technique is applied to enhance the image's lighting. Besides, limited adaptive histogram equalization (CLAHE) is imposed to control the over-enhancement of specific region's contrast. Modified L, U, and V components are recovered via the inverse discrete wavelet transform (IDWT), and the image is again converted into RGB space. This output is fused with a histogram equalized image using weighted fusion followed by a high boost filter to get the final enhanced output. Experimental outcomes are achieved to validate the efficacy and robustness of the suggested strategy using quality evaluators such as Entropy, NIQE, and BRISQUE rankings explored on ExDark, DPED, and LoLi datasets

Keywords: Contrast enhancement, Histogram equalization, LUV Color space, Discrete wavelet transform, Inverse wavelet transform, Image naturalness.

1. Introduction

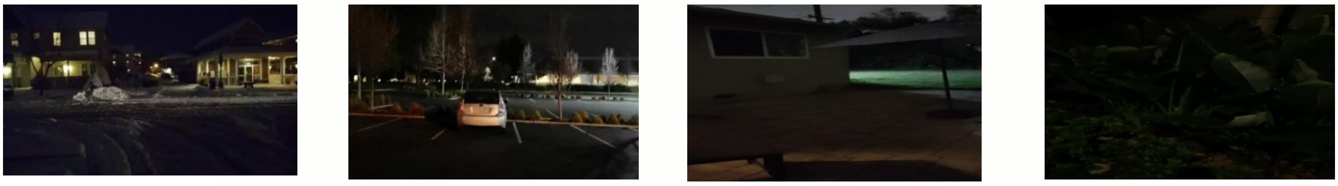
Digital images are crucial in practical uses like satellite television, MRIs, computer tomography, and scientific and technological fields like astronomy and geographic information systems. Scientists have struggled to reconstruct the original image contents from disturbing and noisy images in these various disciplines. The goal of image enhancement is to make it easier for viewers to understand the information contained in images.

When an image's contrast is too low, it creates difficulty in viewing its finer features because of uneven or insufficient lighting. To achieve enhanced results, local and global variation consistent with the original intensity as a part of "naturalness preservation" is strived. Researchers have suggested various enhancing techniques to improve the visual appeal of these images or achieve high-visibility effects. Figure 1 shows a sample specimen of low-light images from different datasets.

Histogram equalization (HE), a statistics-based approach, is one of many pixel modulation schemes that directly alter the image's pixel intensity for improvement. Artifacts and a lack of naturalness could result from this kind of approach.

However, the settings require manual construction with past understanding, and the spatial information is not considered while acting on each pixel. The non-linear gamma correction approach greatly performs in challenging light circumstances due to the extensive usage of mapping curves. More inner data of the picture may be acquired with the aid of changing pixel data to different domain names using strategies like discrete Fourier

Sample specimen from ExDark Dataset



Sample specimen from LoLi Dataset

Sample specimen from DPED Dataset

transform (DFT), discrete cosine transform (DCT), and discrete wavelet transform (DWT). These solutions, which may damage potentially helpful visual cues, combine spatial reconstruction techniques like homomorphic filtering with frequency-domain filters to produce such effects.

An enhancement method produces an image of higher quality for a specific use, and it can do this by reducing noise or boosting visual contrast. Noise typically taints the data sets that image sensors collect. The relevant data quality may be lowered by unreliable equipment, issues with the data collection procedure, and interfering natural events. Distortions can occur in a variety of ways. One of the most frequent instances is distortion brought on by additive white Gaussian noise, subpar image collection, or sending the image data through noisy communication channels. Impulse and speckle noises are two additional categories of noise.

Additionally, compression and transmission faults also have the potential to cause noise. Thus, denoising is frequently an essential initial step before evaluating the picture data. An effective denoising technique must be used to compensate for such data distortion. Because noise reduction generates artifacts and blurs images, image denoising is still difficult for researchers. An old but current industrial issue is the denoising of electronically distorted images.

The two main ways to denoise images are spatial and transform domain filtering methods. The idea behind spatial filters is that noise is present in the higher frequency spectrum; hence they apply a low pass filter to groups of pixels. Spatial low-pass filters blur edges in signals and images while smoothing away noise, in contrast to high-pass filters, which can sharpen edges and boost spatial resolution while magnifying the noisy background.

The spatial domain approach directly works on pixels, but the transform domain method first performs an image's Fourier transform before returning it to the spatial domain. Pixel values can be changed using the spatial domain method. A new type of signal analysis, wavelet analysis, is much more effective than Fourier analysis when the signal has temporal behavior or discontinuities. Wavelet transforms have been extensively studied for additive noise reduction of signals and images. A scale-based decomposition is provided using the wavelet transform.

Wavelet transforms of images often consist of a limited number of large coefficients and many small coefficients. As a result, there are two probability states for each wavelet coefficient: significant and insignificant. Convolution and lifting scheme methods are used to implement the discrete wavelet transform (DWT) for discrete-time signals. The fundamental process involves downsampling the outputs by a factor of two after applying low and high pass filters.

When the outcome of the low pass channel is subjected to the same decomposition, a two-level wavelet transform results; this method is repeated in a dyadic

transform. The lifting technique can be applied beforehand to enhance or denoise the image and can also be applied in reverse to bring back the original image. This paper is composed of six sections. The existing research on enhancing low-light contrast in dark images is found in Section 2. In Section 3, the recommended Contrast Enhancement method is shown. Section 4 evaluated the suggested method using the ExDark, DPED, and LoLi datasets, which distorts the findings. Section 5 summarizes the whole work, while section 6 focuses on its constraints and potential scope.

2. Literature survey

This section reviews the state-of-the-art techniques for enhancing the quality of degraded images. A few efforts to improve image detail have been published. Multiple input images were acquired under varying lighting conditions, and researchers devised various algorithms using different color spaces in spatial and transform domains.

The technique known as "Histogram Equalization" (HE) is often used to enhance image contrast within a spatial domain set (Gonzalez & Woods, 2002). This approach has a condensed build time and is flexible to use. The histogram equalization process locates the pixel intensities that recur the most frequently and distributes them evenly throughout the image. HE is a particularly helpful technique for spreading intensities uniformly across the entire image because images in the dark have bright and dark regions. This method's drawback is that the output that has been equalized could contain overly bright areas. Two modified versions of the HE approach have been created in response to this restriction: "Adaptive HE" (AHE) (Pizer & Amburn, 1987), and "Contrast Limited Adaptive HE" (CLAHE) (Mhan & Simon, 2020). The mentioned techniques aim to improve results by working on multiple regions with diverse histograms applied to less illuminated photos.

There are numerous methods for figuring out the clipping threshold values in these procedures. "Exposure-based Sub-Image HE" (ESIHE) divides images into

image is changed to a space with a different hue-saturation intensity. This intensity component is

way to produce a multilevel decomposition. The lifting scheme is a more effective wavelet transform technique than the convolution approach of the wavelet

sub-images with different intensities and is used to increase output effectiveness (Singh & Kapoor, 2014). Recently, another approach to enhancing and balancing the brightness of dark images is using Kekre's LUV color space that enhances the brightness of the input image and blends it with the output of HE (Pardhi & Thepade, 2020). The non-uniformly lighted image was split into five sub-images, and a modified method was introduced by giving each histogram's cumulative density function a nonlinear weight correction. The result is a modified intensity mapping for overexposed and underexposed (Hidayah & Ashidi, 2021). Another idea is to use quick local Laplacian filtering that enhances only the local details of the bright and dark regions (FLLF). First, the average brightness for each place is calculated to estimate the region of enhancement (RoE) of every image in the bright and dark parts. The authors employed a multiresolution technique to create the fused image for pixels in the RoE, extracting the darkest or brightest details using the modified faster local Laplacian filtering as the detail extraction mechanism (Wang & He, 2021).

Many authors offer an alternative approach to histograms grounded on the Retinex hypothesis. The algorithms assume the reflection to be a modified outcome by eliminating and estimating the illumination. Using a Gaussian filter, Single Scale Retinex (SSR) (Jobson & Rehman, 1997), Multiscale Retinex (MSR) (Jobson & Rehman, 1997) split reflection and illumination. The lack of lighting improves brightness and detail, but a center/perimeter approach may overemphasize the reported results. MSRCR negates the shortcomings mentioned above. Adaptive Retinex-based technology minimizes halo artifacts by applying adaptive filters to the luminance channels (Meylan & Susstrunk, 2006). As recommended, Multiscale Retinex can also be used in OLED displays that give the right gain for good visibility and save power without flickering artifacts (Yeon, 2006). Another technology focuses on image quality with complex atmospheres. Here, to advance the image quality of photographs, MSR is applied in consideration of image quality learning (Liu & Lu, 2017). A Retinex-based high-speed algorithm (RBFA) has been introduced to restore low-brightness, suppressed content. Here, the original dark

stretched using a linear function of dynamic range (Liu, 2021). Recently, a new method that combines color restoration and denoising has been proposed. Here, paired pictures are subjected to modified Retinex-decomposition to produce reflectance and illumination maps. This prevents the use of flexible joint function over smoothing (Yu & Li, 2022).

To improve the brightness of dark photographs, the author used an automatic gamma correction method with luminance pixel probability scattering. To reduce processing complexity, these algorithms use temporary information about the differences between each frame to correct dark images (Huang & Cheng, 2013). By separating the luminance components of the YCbCr color space, a new method of dynamic range adjustment (AMIDRA) and less illuminated image enhancement has been established (Yang & Li, 2018). A new technique called Adaptive Image Enhancement (AIEM) (Wang & Chen, 2019) corrects low-light images by converting RGB images into HSV space and uses Weber-Fechner's law to build intensity components. Based on the distribution profile of the lighting component, the adaptive adjustment for enhancement produces two images. Finally, merging the two images will improve the resulting image. Recently, adaptive gamma correction has been used with Retinex theory. Training sets establish an association between image exposure and features under maximum entropy generation (Yu, 2021). A new improvement algorithm was recently presented that can improve photos close to the boundary of separation and images well within the barrier. Utilizing nonlinear weight modifications, the algorithm's fundamental concept is integrating several AGC-enhancing functions. Using these weight adjustments, both contrast and brightness have been changed (Sengupta & Biswas, 2021).

As proposed by (Demirel & Anbarjafari, 2008) and (Demirel & Anbarjafari, 2010), some frequency domain approaches for enhancing low-contrast images are non-uniform contrast and medium range based on the scaling of individual values. Ideal for bright images. Compared to previous approaches, the methods are (Atta & Ghanbari, 2013) and (Atta & Abdel-Kader, 2015), which improve the performance of photos in the medium brightness range). Another approach to improving dark images by the combination of CLAHE-DWT. To accentuate the low-frequency coefficients and reduce the noise amplification without affecting the high-frequency coefficients, the original image is first divided into low and high-frequency components by DWT. This is so since the high-frequency components comprise the majority of noise in the original image. Finally, get the inverse DWT of new coefficients and reconstruct the image. To avoid over-amplification, the average of the original reconstructed image is used from the originally proposed weighting factor (Lidong & Wei, 2015). In current years, new tactics have been introduced that change the wavelet transform. In this approach, a fuzzy dot matrix and a planar feature matrix are constructed, new values for the gradient mean and image quality index are calculated, and the original image is (Qing & Feng, 2021).

Several techniques based on the fusion process have been presented to improve low-contrast photography. A procedure was introduced to create many photos at different exposures by mapping the intensity function to the input image (Lim & Park, 2006). Combining domain-specific information with a hybrid image enhancement approach produces more detailed, low-noise images. Improve medical images using frequency and spatial domain techniques (Muslim & Khan, 2019). Establishing stability between contrast and brightness using image fusion optimized for cuckoo search is a more advanced technique in this area. Authors first apply a Cuckoo search-based optimization approach to develop an improved photo duo to generate two sets of ideal parameters. The first set has high contrast and sharpness, and the second is bright and detailed without affecting sharpness. The fusion method combines the two improved images to produce a balanced contrast and brightness output (Lalit & Viney, 2021). In the most recent method of improvement, the histogram is divided into three sub-parts, indicating the dark, grey, and brilliant sections of the histogram according to the homogeneity value. Then, local changes in each sub-section are done using 2D geometric scaling and adaptive gamma. The 2D translation technique is used to join these altered sub-sections once more. On the other hand, the entire histogram is given a global gamma transformation. The finishing transformation matrix is then created by integrating the local-global transformations that have already been computed (Sarkar & Halder, 2021).

The need to introduce the proposed method is because of the following limitations of the methods discussed so far are listed below

1. Occurrence of noise and color distortion in an image (Wang & He, 2021)
2. Under enhancement of image in the dark region (Yang & Li, 2018)

3. Loss of details at the edges of an image (Atta & Abdel-Kader, 2015)
4. brightness in some regions where street lights or bright sources are present (Lalit & Viney, 2021)

To overcome the above drawbacks from the existing method, the proposed method is founded on the following key contributions

- Use of Kekre's LUV color space as it improves the quality of recreated colored output image and minimizes color distortion

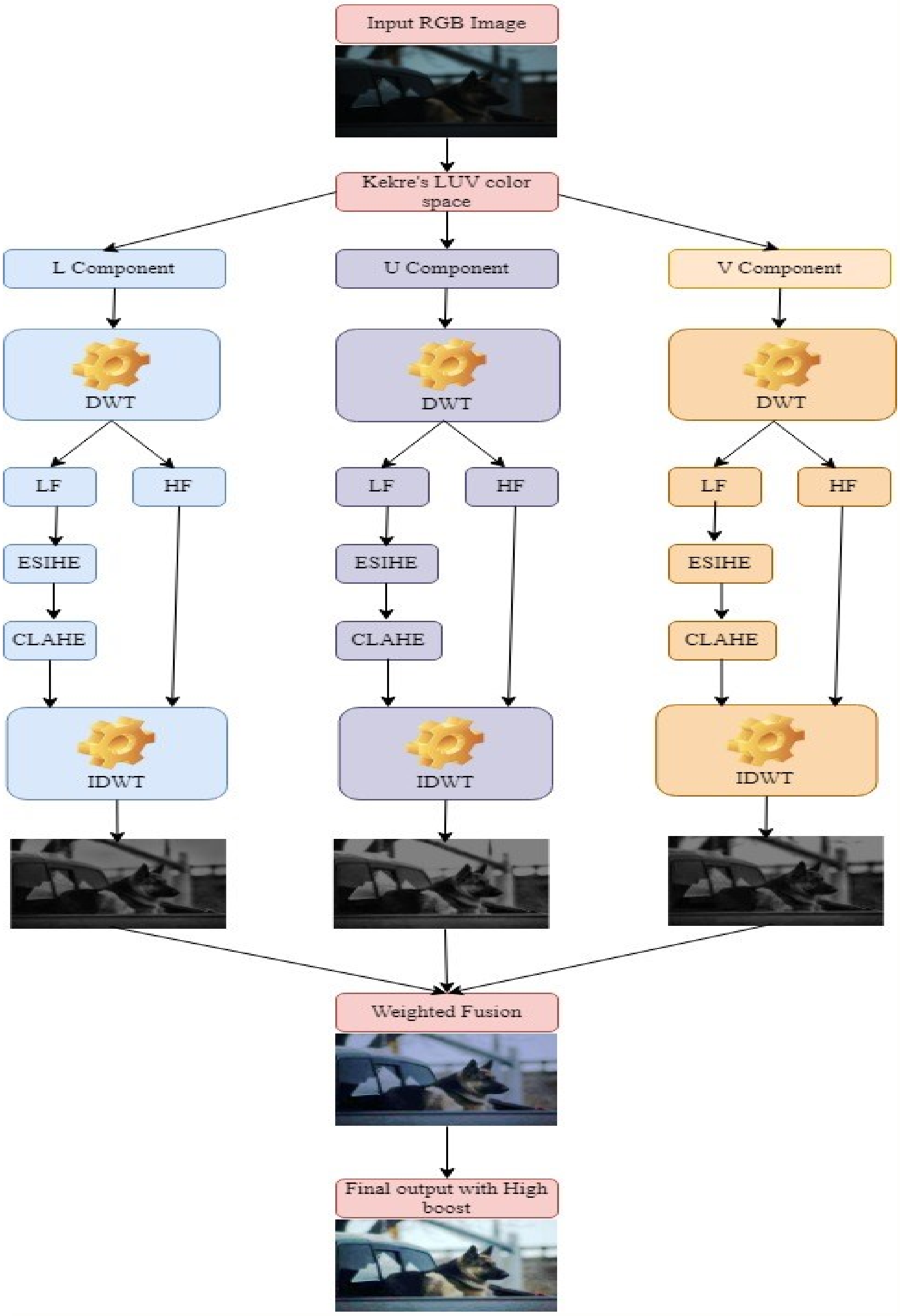


Figure 2. Flow chart of Proposed Method

DOI: 10.6977/IJoSI.202406_8(2).0002
S. D. Thepade, P. M. Pardhi. /Int. J. Systematic Innovation, 8(2), 17-30 (2024)

- Combination of linear weights for recovered RGB image and histogram equalized image to balance the brightness in the resultant image

- To control the over-brightness, exposure and contrast limited techniques are applied on low-frequency components after decomposition by DWT

3. Methodology and Scope

In this part, a technique for enhancing non-uniform illumination photos to boost their quality is provided. Figure 2 depicts the proposed technique's framework and is explained in five sections. The first section details the conversion of RGB to Kekre's LUV color space & vice versa. The discrete wavelet transform and the inverted discrete wavelet transform are applied to the image, as explained in Section 2. Low light image enhancement algorithms used here, i.e., CLAHE & ESIHE, are enlightened in sections 3 and 4, respectively. The final part explains the weighted fusion to get enhanced output.

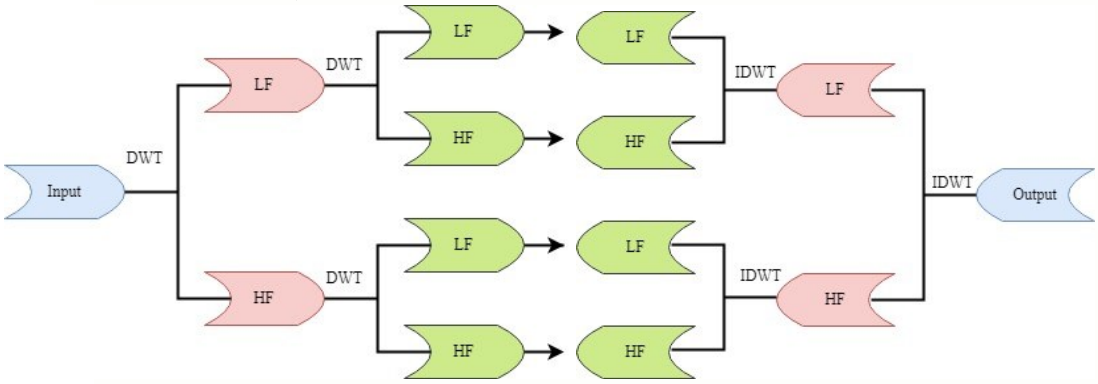


Figure 3. DWT and IDWT Flow diagrams

3.1 RGB to Kekre LUV Conversion

Initially, the low light RGB image is transformed into Kekre's LUV space. The vice versa transformation is as shown in equations 1 and 2. The poorly conditioned image is initially changed into luminance-chromaticity space. The following RGB to LUV conversion matrix shows a color image's L, U, and V components computed on corresponding R, G, and B components.

$$\begin{bmatrix} \boldsymbol{L} \\ \boldsymbol{U} \\ \boldsymbol{V} \end{bmatrix} = \begin{bmatrix} \mathbf{1} & \mathbf{1} & \mathbf{1} \\ \mathbf{-2} & \mathbf{1} & \mathbf{1} \\ \mathbf{0} & \mathbf{-1} & \mathbf{1} \end{bmatrix} \begin{bmatrix} R \\ G \\ B \end{bmatrix} \quad (1)$$

The reverse can be achieved by the LUV to RGB conversion matrix as equation 2

$$\begin{bmatrix} \boldsymbol{R} \\ \boldsymbol{G} \\ \boldsymbol{B} \end{bmatrix} = \begin{bmatrix} \mathbf{1} & \mathbf{-2} & \mathbf{0} \\ \mathbf{1} & \mathbf{1} & \mathbf{-1} \\ \mathbf{1} & \mathbf{1} & \mathbf{1} \end{bmatrix} \begin{bmatrix} L \\ U \\ V \end{bmatrix} \quad (2)$$

3.2 DWT & IDWT

L, U, and V components obtained as an output from equation 1 undergo wavelet transformation as shown in figure 3, to decompose into low and high-frequency coefficients. When two-dimensional denoising signals, such as images and wavelets, are frequently used, selecting a wavelet type and level N of decomposition is the initial step. Here, decomposition is accomplished using the Haar wavelet. The two-dimensional image is transformed into wavelets using these wavelets. Determining threshold values for each level from 1 to N comes after the image file has been broken down. Reconstructing the image from the updated levels is the last stage, where an inverse wavelet transform is used, as shown in Figure 3.

3.3 ESIHE

The exposure-based sub-image histogram equalization method is used to improve the decomposed low-frequency component, as is explained in this section. The whole dynamic range is not used in photos with poor contrast. Images with low-intensity exposure have histogram bins concentrated toward the darker grey levels, whereas those with high-intensity exposure have histogram bins concentrated toward the brighter part. The categories of underexposed and overexposed photos can be broadly categorized based on this intensity exposure.

The ESIHE algorithm is displayed here. Three

DOI: 10.6977/IJoSI.202406_8(2).0002
S. D. Thepade, P. M. Pardhi. /Int. J. Systematic Innovation, 8(2), 17-30 (2024)

steps comprise the algorithm: choosing the exposure threshold, clipping the histogram, and subdivision and equalization. The following subsection detailed each step

Step 1: Calculate the image's histogram $h(k)$.

Step 2: Calculate exposure and threshold parameter X_a

$$exp = \frac{1}{L}\frac{\sum_{k-1}^{L} h(k)k}{\sum_{k-1}^{L} h(k)} \quad (3)$$

Here L represents the total amount of grey levels, and the histogram is denoted by $h(k)$

The exposure-related parameter X_a provides the grey level value of the barrier that acts as a separator to divide the image into underexposed and overexposed sub-images.

$$X_a = L(1 - exp) \quad (4)$$

Depending on whether the exposure value is less than or more than 0.5 for a picture with a dynamic range of 0 to L, this parameter can reach values higher or less than L/2 (grey level).

Step 3: Computation of the clipping threshold T_c and clip $h_c(k)$, the histogram

$$T_c = \frac{1}{L}\sum_{k=1}^{L} h(k) \quad (5)$$

For $h(k) \geq T_c$ $\quad$ $h_c(k) = T_c$

where $h(k)$ and $h_c(k)$ indicate the original and clipped histogram, respectively.

Step 4: Utilizing the threshold setting X_a, split the clipped histogram into two sub-parts to obtain the underexposed and overexposed regions.

Step 5: Individual sub-histograms should be subjected to histogram equalization.

Step 6: Combination of these sub-parts in a single image for analysis.

Compared to other approaches, the ESIHE method produces images with excellent contrast enhancement and control over over-enhancing, making it a viable alternative for under-exposed images.

3.4 CLAHE

The output of the previous step is again equalized using CLAHE, which improves the local details. The implementation of CLAHE is given in the following steps

Step 1: Separates the original intensity image into contextual parts that don't overlap. MxN is the same as the total number of image tiles.

Step 2: Histogram of every region calculated using the current grey levels.

Step 3: computation of the limited contrast histogram (CL) value

$$N_{Avg} = \frac{(N_r X * N_r Y)}{N_{gray}} \quad (6)$$

Here N_{Avg} stands for the average pixels, and N_{gray} stands for the number of grey levels. The values represent the region's X and Y dimensions $N_r X$ and $N_r Y$ respectively. CL can then be calculated as

$$N_{CL} = N_{clip} * N_{avg} \quad (7)$$

where N_{CL} stands for actual CL and N_{clip} stands for normalized CL occupying the range from 0 to 1. Pixels having higher intensity than N_{CL} is clipped, and the notation shows the clipped pixels N_{clip}. Now, each grey level's average remaining pixel is calculated using the formula

$$N_{avggray} = N_{clip} / N_{gray} \quad (8)$$

Histogram clipping can be carried out according to certain conditions, such as (1) clipping to value CL for higher values than CL. (2) The pixel value equals CL again if pixel intensity + $N_{avggray}$ is larger compared to CL; again, the pixel value equals CL. (3) for the cropped histogram original intensity + CL value.

Step 4: Redistribution of the leftover pixels throughout the intensity range

Step 5: New pixel assignments for grey levels should be calculated.

Step 6: The CLAHE (Y) output then undergoes color restoration steps as applied to gray images suggested in (Abdullah & Kabir, 2007).

After clipping the histogram portion above a threshold, the CLAHE algorithm reallocates the clipped pixels against every grey level. This procedure can somewhat reduce the noise enhancement problem. For some uses, the noise is still intolerable. Additionally, due to over-enhancing, it can lose some of the details in some areas of the supplied image.

Modified low- and high-frequency components are subjected to the inverse wavelet transform.

3.5 Wavelet Fusion

Output from the above step is fused linearly with traditional histogram equalization having weights as 0.7 and 0.3, respectively, as shown in equation 9, followed by a high boost algorithm to preserve edges in output enhanced image.

$$Output_{fused} = 0.7 * Output_1 + 0.3 * Output_2 \quad (9)$$

In the equation above, a small weight is in m multiplication with the HE output to reduce the impact distortion in color.

4. Result and Discussion

The experimental outcomes of CLAHE, ESIHE, the existing method, and the proposed technique are elaborated in the current section. The experimentation is done on three separate datasets containing different low-light photos. The ExDark, LoLi, and DPED datasets were used in this study. No-reference image quality

Evaluator (NIQE), and Blind/Reference Image Spatial Quality Evaluator (BRISQUE). Here the higher entropy score implies a better image quality. NIQE and BRISQUE are other no-reference image quality evaluators. A lesser NIQE or BRISQUE score implies a better enhancement.

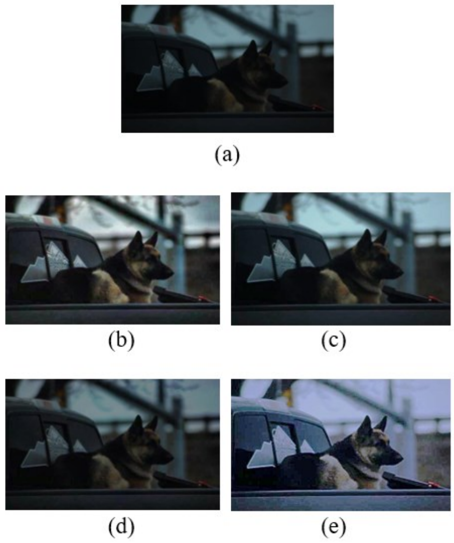


Figure 4. (a) Original low light image from ExDark Dataset. Result of (b) CLAHE (Mohan & Simon, 2020) (c) ESIHE (Singh & Kapoor, 2014) (d) CLAHE-DWT (Lidong & Wei, 2015) (e) Proposed Method

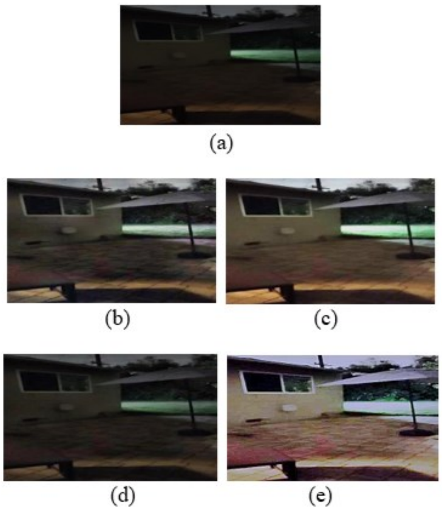


Figure 5. (a) Original low light image from LoLi Dataset. Result of (b) CLAHE (Mohan & Simon, 2020) (c) ESIHE (Singh & Kapoor, 2014) (d) CLAHE-DWT (Lidong & Wei, 2015) (e) Proposed Method

Figure 6. (a) Original low light image from DPED Dataset. Result of (b) CLAHE (Mohan & Simon, 2020) (c) ESIHE (Singh & Kapoor, 2014) (d) CLAHE-DWT (Lidong & Wei, 2015) (e) Proposed Method

The comparison results of low-light photos for various techniques are shown in Figures 4, 5, and 6. It implies that the proposed method reduces over-enhancing and color distortion compared to earlier methods while significantly improving low-light image enhancement. **Tables 1** through **9** quantitatively display findings from various methodologies.

Tables 1, 2, and **3** highlight the average Entropy, NIQE, and BRISQUE scores of different dark images experimented with over the ExDark dataset. It is perceived that the estimated method of enhancing poorly illuminated images using wavelet transform gives the highest score for Entropy, implying better enhancement results compared to other methods. Concerning the NIQE score, the suggested method ranked second highest after the existing method. The BRISQUE score is the lowest for the proposed method, indicating the best enhancement results.

The experimental outcomes from tables 4, 5, and 6 depict the evaluation of the LoLi dataset. Notably, the proposed algorithm achieves the highest scores among all methods evaluated by both Entropy and BRISQUE quality evaluators. These findings substantiate the efficacy of the proposed algorithm in enhancing results, outperforming existing methods significantly.

Table 1. Average Entropy Score of ExDark Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Bicycle	5.9	5.3	5.6	6.5
Boat	6.9	6.5	6.6	7.2
Bottle	5.6	4.9	5.3	6.5
Bus	5.7	5.0	5.5	6.6
Car	5.1	4.5	4.8	6.2
Cat	5.8	5.0	5.4	6.6
Chair	5.2	4.6	5.0	6.2
Cup	6.2	5.5	5.9	6.9
Dog	5.6	4.9	5.3	6.5
Motorbike	6.2	5.8	6.0	6.9
People	4.7	4.3	4.6	5.5
Table	5.6	5.0	5.3	6.7
Average	**5.7**	**5.1**	**5.4**	**6.5**

Table 2. Average NIQE Score of ExDark Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Bicycle	5.4	5.5	5.0	5.0
Boat	4.5	4.9	4.4	4.5
Bottle	4.8	5.5	4.8	4.9
Bus	4.8	5.1	4.7	4.8
Car	5.1	5.7	5.2	5.4
Cat	4.4	4.6	4.3	4.2
Chair	5.7	6.5	5.5	5.8
Cup	4.0	4.4	4.0	4.0
Dog	4.8	5.2	4.8	4.8
Motorbike	4.7	5.3	4.6	4.8
People	5.3	5.5	5.1	5.1
Table	5.1	6.1	5.2	5.9
Average	**4.9**	**5.3**	**4.8**	**4.9**

Table 3. Average BRISQUE Score of ExDark Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Bicycle	36.0	36.1	37.4	34.5
Boat	27.2	32.2	30.9	28.4
Bottle	39.0	42.5	41.0	30.6
Bus	37.2	40.9	40.0	30.9
Car	38.4	42.9	40.0	37.8
Cat	39.5	42.4	41.4	33.4
Chair	40.9	41.6	40.5	36.2
Cup	39.2	43.1	42.2	31.7
Dog	41.8	44.3	41.5	36.4
Motorbike	37.1	33.7	36.0	29.9
People	41.9	44.2	42.2	37.6
Table	40.3	44.7	40.8	35.8
Average	**38.2**	**40.7**	**39.5**	**33.6**

Table 4. Average Entropy Score of LoLi Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Huawei	6.2	5.2	5.7	7.3
LG	6.5	5.2	5.8	7.6
Oneplus	5.2	4.1	4.6	7.3
Oppo	7.3	6.4	6.7	7.6
Pixel	7.6	6.9	7.1	7.7
Vivo	6.2	5.1	5.6	7.3
Xiaomi	5.8	4.4	5.1	7.2
iPhone	6.4	5.6	5.9	7.3
Average	**6.4**	**5.4**	**5.8**	**7.4**

Table 5. Average NIQE Score of LoLi Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Huawei	4.0	4.4	4.5	5.3
LG	3.6	4.3	3.8	4.5
Oneplus	8.4	9.7	8.4	9.2
Oppo	3.5	3.8	3.4	4.9
Pixel	3.1	3.0	2.9	3.7
Vivo	4.9	5.4	5.0	6.6
Xiaomi	4.5	5.7	5.1	6.3
iPhone	3.9	4.1	4.0	4.9
Average	**4.5**	**5.1**	**4.6**	**5.7**

Table 6. Average BRISQUE Score of LoLi Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Huawei	37.4	39.9	41.7	31.7
LG	36.8	41.0	41.8	38.1
Oneplus	51.0	57.5	48.3	46.5
Oppo	28.4	32.6	32.8	20.8
Pixel	24.8	27.6	28.1	17.3
Vivo	40.1	43.0	42.4	41.1
Xiaomi	42.6	47.4	42.7	38.5
iPhone	33.1	33.9	36.4	29.7
Average	**36.8**	**40.4**	**39.3**	**33.0**

Table 7. Average Entropy Score of DPED Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Blackberry	7.7	7.6	7.4	7.6
Canon	7.5	7.3	7.1	7.5
iPhone	7.6	7.1	7.0	7.6
Sony	7.8	7.6	7.4	7.7
Average	**7.6**	**7.4**	**7.2**	**7.6**

Table 8. Average NIQE Score of DPED Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Lidong & Wei, 2015)	Proposed
Blackberry	4.0	3.4	3.6	5.0
Canon	3.3	2.9	3.3	4.4
iPhone	2.7	2.9	2.5	4.1
Sony	3.5	3.0	3.1	4.5
Average	**3.4**	**3.0**	**3.1**	**4.5**

Table 9. Average BRISQUE Score of DPED Dataset

Image	CLAHE (Mohan & Simon, 2020)	ESIHE (Singh & Kapoor, 2014)	CLAHE-DWT (Li-dong & Wei, 2015)	Proposed
Blackberry	30.4	26.5	24.0	22.1
Canon	21.2	27.5	28.5	22.3
iPhone	21.1	28.6	26.4	19.0
Sony	20.4	21.4	26.4	19.9
Average	**23.3**	**26.0**	**26.3**	**20.8**

Tables 7, 8, and **9** highlight the performance evaluation of techniques on the DPED dataset. Significantly, the recommended technique demonstrates impressive results, boasting high scores for Entropy while recording the lowest BRISQUE score among the experimented methods. This underscores the effectiveness of the recommended technique in optimizing results on the DPED dataset.

By giving less weight to the HE output and more weight to the output of the proposed method, the over-enhancement effect in output can be reduced to a moderate level due to the linear fusion used in the proposed method.

5. Conclusion

It is crucial but challenging for photographs with poor lighting to improve the contrast and restore the details. Poor lighting circumstances and factors, including light absorption, reflection, bending, and scattering, result in dimness and distortion; such images may lose contrast and degrade. It's possible that the current algorithms for picture enhancement can't effectively boost contrast and restore color for low-light photographs. As a result, this paper, the wavelet-based algorithm for enhanced fusion has five main steps: conversion of RGB to LUV color spaces, decomposition of each component using wavelet transform, applying ESIHE to get an exposure-based enhancement of dark and bright regions separately, applying CLAHE to control over bright regions, and weighted fusion with traditional HE method followed by edge preservation.

The proposed algorithm can efficiently accomplish contrast enrichment based on experimentations performed on various datasets having differently captured categories of poorly illuminated images against different evaluation parameters such as Entropy, NIQE, and BRISQUE. The method outperforms existing enhancement algorithms in visual performance and quantitative evaluation by giving a higher Entropy score and a lower BRISQUE score across three different datasets.

6. Limitations and future research

With the experiments performed on different datasets having a variety of low-light images, noise is observed in a few patches, affecting the NIQE score. As a corrective measure, the proposed method can be added with a noise amplification feature compared to the results of diverse fusion methodologies and contrast enhancement metrics. Further, similarly, the findings would be tested by combining the output from other local and global methods. Our goal is to construct a quantifiable assessment of the effectiveness of contrast-enhancement algorithms based on various measures described in the paper.

Statements and Declarations

Funding: Not applicable

Conflict of interest: Both authors declare no conflict of interest.

References

Abdullah-Al-Wadud, M. & Kabir, M. (2007). A Dynamic Histogram Equalization for Image Contrast Enhancement. IEEE Transactions on Consumer Electronics. 53(2), 593–600

Atta, R. & Abdel-Kader, R. (2015). Brightness preserving based on singular value decomposition for image contrast enhancement. Optics International Journal Light and Electron Optics. 126(7-8), 799-803

Atta, R. & Ghanbari, M. (2013). Low-contrast satellite image enhancement using discrete cosine transform pyramid and singular value decomposition. IET Image Processing, 7(5), 472-483

Demirel, H. & Anbarjafari, G. (2008). Image Equalization based on singular value decomposition. International Symposium on Computer and Information Science, 1-5

Demirel, H. & Anbarjafari, G. (2010). Satellite Image Contrast Enhancement Using Discrete Wavelet Transform and Singular Value Decomposition. IEEE Geoscience and Remote Sensing Letters. vol. 7, No. 2, 333-337

Gonzalez, R. & Woods, R. (2002). Digital image processing. Reading: Pearson Education

Huang, S. & Cheng, H. (2013). Efficient Contrast Enhancement Using Adaptive Gamma Correction with Weighting Distribution. IEEE Transactions on Image Processing. 22(3), 1032–1041

Jobson, D. & Rahman, Z. (1997). A multiscale retinex for bridging the gap between color images and the human observation of scenes. IEEE Transaction on Image Processing. vol. 6, no. 7, 965–976

Jobson, D. & Rahman, Z. (1997). Properties and performance of a center/surround retinex. IEEE Transaction on Image Processing. vol. 6, 451–462

Lalit, M., Viney, L., Prasant, K. & János, A. (2021). Contrast and brightness balance in image enhancement using Cuckoo Search-optimized image fusion. Journal of King Saud University - Computer and Information Sciences, 7247-7258

Lidong, H., Wei, Z., Jun, W., Lidong, H. & Zebin, S. (2015). Combination of contrast limited adaptive histogram equalisation and discrete wavelet transform for image enhancement. IET Image Processing. 9(10), 908–915

Lim, B. & Park, H. (2006). High dynamic range for contrast enhancement. IEEE Transaction Consumer Electron. vol. 52, no. 4, 1454-1462

Liu, H. & Lu, H. (2017). Image enhancement for outdoor long-range surveillance using IQ-learning multiscale Retinex. IET Image processing. 11(9), 786–795

Liu, S. (2021). Retinex-Based Fast Algorithm for Low-Light Image Enhancement. Entropy. 23, 746

Meylan, L. & Susstrunk, S. (2006). High dynamic range image rendering with a retinex-based adaptive filter. IEEE Transaction on Image Processing. vol. 15, no. 9, 2820–2830

Mohan, S. & Simon, P. (2020). Underwater Image Enhancement based on Histogram Manipulation and Multiscale Fusion. Procedia Computer Science. vol. 171, 941-950

Muslim, H. & Khan, M. (2019). A knowledge-based image enhancement and denoising approach. Computational and Mathematical Organization Theory. (25), 108-121

Nor Hidayah S., Nor Ashidi M. & Hariyanti, S. (2021). Nonlinear Exposure Intensity Based Modification Histogram Equalization for Non-Uniform Illumination Image Enhancement. IEEE Access, 93033-93061

Pardhi, P. & Thepade, S. (2020). Enhancement of Nighttime Image Visibility Using Wavelet Fusion of Equalized Color Channels and Luminance with Kekre's LUV Color Space. 2020 IEEE Bombay Section Signature Conference (IBSSC), 96-101

Pizer, S. M.& Amburn, E. P. (1987). Adaptive histogram equalization and its variations. Computer Vision, Graphics and Image Processing. 39(3), 355-368

Qing, H. & Feng P. (2021). Image local fuzzy enhancement method based on Improved Wavelet Transform. 2021 13th International Conference on Measuring Technology and Mechatronics Automation (ICMTMA), 282-286

Sarkar, K., Halder, T.K. & Mandal, A. (2021). Adaptive power-law and cdf based geometric transformation for low contrast image enhancement. Multimed Tools Appl 80, 6329–6353

Sengupta, D., Biswas, A. & Gupta, P. (2021). Correction to: Nonlinear weight adjustment in adaptive gamma

DOI: 10.6977/IJoSI.202406_8(2).0002
S. D. Thepade, P. M. Pardhi. /Int. J. Systematic Innovation, 8(2), 17-30 (2024)

correction for image contrast enhancement. Multimed Tools Appl 80, 6507

Singh, K. & Kapoor, R. (2014). Image enhancement using exposure based Sub Image Histogram Equalization. Pattern Recognition Letters. 36, 10–14 Wang, C., He, C. & Xu, M.: (2021). Fast exposure fusion of detail enhancement for brightest and darkest regions. Vis Comput 37, 1233–1243

Wang, Y. & Chen, W. (2019). Adaptive image enhancement method for correcting low-illumination images. Information Sciences. 496:25, 41

Yang, K. & Li, H.: (2018). An Adaptive Method for Image Dynamic Range Adjustment. IEEE Transaction on Circuits and Systems for Video Technology. 29(3), 640-652

Yeon-Oh, N. (2014). Power-Constrained Contrast Enhancement Algorithm Using Multiscale Retinex for OLED Display. IEEE Transactions on Image Processing. 23(8), 3308–3320

Yu, W. (2021). GLAGC: Adaptive Dual-Gamma Function for Image Illumination Perception and Correction in the Wavelet Domain. Sensors. 21, 845

Yu, X., Li, H. & Yang, H. (2022). Two-stage image decomposition and color regulator for low-light image enhancement. Vis. Comput, 39(3), 1-11

AUTHOR BIOGRAPHIES

Dr Sudeep D. Thepade is a professor at Pimpri Chinchwad College of Engineering, Pune, India. To his credit, he has more than 320 research articles in Journals and Conferences. He is a reviewer for several International Journals, including IEEE and IET. He is a member of international bodies like IAENG, IACSIT, and ICGST.
He is a member Board of studies and Research Review Committee at several Universities. He is guiding a few Ph.D. Scholars and have guided many Masters and bachelor's projects.

Mr Pravin M. Pardhi is a PhD scholar in the Department of Technology, SPPU, Pune, India. He received his master's degree from SGGSIET Nanded in 2013 and his bachelor's degree from SRTMU Nanded in 2010. His research interests include Image Processing and Computer Vision

DOI: 10.6977/IJoSI.202406_8(2).0003
C. Toth, B. Fehervolgyi, et al. /Int. J. Systematic Innovation, 8(2), 31-43 (2024)

Three possible sources of inconsistency in an innovation ecosystem

Csilla Toth[1], Dr. Beata Fehervolgyi[2]*, Dr. Zoltan Kovacs[2]*, Dr. Andras Hary[1]*
[1] ZalaZONE Science Park Ltd., Hungary
[2] Faculty of Management Science, University of Pannonia, Hungary
* Corresponding author E-mail: andras.hary@apnb.hu
(Received 22 August 2023; Final version received 19 April 2024; Accepted 23 April 2024)

Abstract

One of the success factors of an innovation ecosystem is the willingness of its actors to cooperate, which depends on a number of factors. As usual, cooperation needs a common language among the concerned parties and opposite sides, the identification of serious differences of actors might contribute to preparing and managing a collaborative culture. In the present analysis, the authors approach the topic from an operational management perspective and examine the actors of an ecosystem through the elements of a general service management framework model. Based on this, it is possible to point out differences through various factors to determine possible conflict sources. The aim of the study is to show a method for the identification of potential points of inconsistency along the four groups of aspects as potential sources of barriers to collaboration. After literature review, the value system, the operational-business philosophy, the methods and the objectives of a research and technology center are analyzed. The presented approach can serve as a general method for identifying inconsistencies in innovation ecosystems. The current methodology is based on a two-dimension one-by-one analysis, further research can extend the approach to a multi-player inconsistency evaluation tool.
Keywords: innovation, innovation ecosystem, value creation, research centers

1. Introduction

An innovation ecosystem can be seen as a system whose participants are suppliers and customers having relations to each other and to external organizations. However, the diversity and structure dynamism of an innovation ecosystem firmly differ from the usual company environment. Therefore, the introductory parts of this paper are first started from the point of view of classic value supply models, then characterization of innovation ecosystem attributes is followed. Finally, service management perspective is taken to focus on specific features of innovation ecosystems in part 3. The main goal is to be able to identify the cooperation potential between the actors of each innovation eco-system based on the various operational aspects. Since the actors are different organizations, cooperation is not self-evident... in fact, it is difficult. This may be due to the fact that companies are afraid to share their business secrets and technological solutions with others, because they see each other as competitors. If we can reach the level where they see each other as partners, we can also increase their willingness to cooperate. All this affects the potential for cooperation.

For this consideration, a general model of producer-supplier systems can be applied to evaluate and understand the functioning of a value creation system, as a basic approach (Figure 1).

Many companies have developed a formal system to govern their operations, such as Toyota Production/Business System (TPS/TBS), Audi Production System (APS), World Class Manufacturing of Unilever (WCM), or in the services sector, the Global Delivery Framework (GDF).

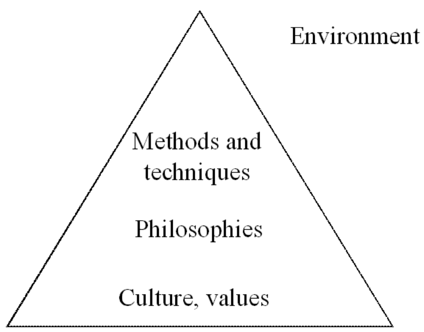


Figure 1. Components of production systems (Smith, 2017)

As production and service companies organize their tasks into supply chains and networks, the organizations involved in the innovation ecosystem also develop a diverse external and internal network of relationships. These relationships, especially internal ones, go beyond traditional customer-supplier relationships and include more informal elements than usual. These are the interactions that help to sustain an innovative and developing operation environment.

Figure 2 is a more detailed unfolding of Figure 1, showing the components in view of the relationship between the two organizations.

The question arises, what is the relationship between the components of the operating system within an innovation ecosystem? Is there a need for alignment and if so, to what extent, for example in terms of objectives, values, and operational philosophy? Is it even worth addressing or should it be left to develop spontaneously? In a related exploratory study, actors were looked at in a specific ecosystem with the aim of identifying what is called incongruities between the elements of the operational systems. During the analysis, pairwise comparisons were performed, as shown in Figure 2.

These elements are subsequently used to define the structural elements of a comprehensive service management framework that can be understood in an innovation ecosystem.

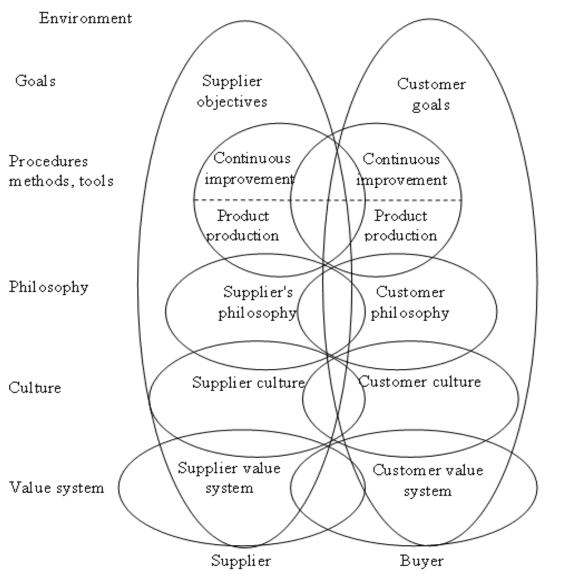


Figure 2. Relationship between the operating system components of organizations (Smith, 2019)

The figure shows that in order for value creation to start within an innovation ecosystem, the interests and needs of suppliers and customers must be taken into account. It is important to understand the actors of the ecosystem, so we arrive at the creation of value by examining the areas of goals, methods, tools, philosophy, corporate culture, and the value creation system. If we understand these characteristics, we can determine the strength and direction of customer and supplier relationships, as well as the parts that need to be improved.

2. Interpretation and general characterization of innovation ecosystems

Considering that innovation ecosystems are also based on value creation mechanisms, the paper refers to the related publications by West and Wood (2008) and Chesbrough et al. (2014), who argue that an open innovation ecosystem comprises communities of different stakeholders who create value through an open approach, linked by competitive and cooperative relationships. This definition describes well the main nature of the innovation ecosystem approach to value creation. However, it is also important to note that an innovation ecosystem is in fact a network of interconnected organizations, organized around a focal company or a platform (e.g. a technology), which includes both value creation and consumption participants, and leads to the development of new value as a result of the innovation (Autio et al., 2014).

A systematic management background usually aims at managing uncertainty or complexity (Duncan, 1972). In the present case, the study is related to a specific type of innovation ecosystem, an open research center. In such a system, both factors are present, since continuous development and technological change imply uncertainty and the need for constant adaptability. In addition, the collaborative nature of innovation ecosystems and the environmental embeddedness are themselves sources of complexity. Jucevicius and Grumadaite (2014) studied innovation ecosystems as complex adaptive systems (CAS). This concept of smart development takes into account the complex dynamic nature of the system and is based on the promotion of productive self-organization rather than imposing top-down linear solutions. A dynamic system is characterized by localized interactions between a large number and variety of actors: universities, businesses, public institutions, society, resources, etc.

The 'harmonious' and complementary cooperation between these actors is crucial to the effectiveness and efficiency of the system as a whole. The identification and analysis of sources of inconsistency within the system is, therefore, an important area of research. Responses to the environment often evolve spontaneously from bottom-up interactions without central guidance. The innovation ecosystem as a complex system cannot necessarily be explained by simple input-output processes. The spontaneous and dynamic interactions between actors in the network can make the system difficult to predict. Advanced innovation ecosystems thus balance on the 'edge of chaos', where creativity and innovativeness are at their highest levels simultaneously (Mason, 2007). Innovation ecosystems can be described as intelligent systems because of their openness, interaction with the environment, self-organization and emergence, adaptability, and flexibility (Murthy and Krishnamurthy, 2003); this should be taken into account when defining the related management methods.

Although it is intended to apply the tools and systems of operational management in understanding the value chain management of innovation ecosystems, it is important to take into account the specialties of the different corporate environments. The innovation ecosystem, as a social system, is the result of the interaction of different cultural, economic, institutional, and technological factors. Thus, the model of social self-organization presented by Fuchs (2002) can be adapted. This model emphasizes the dynamics of actors, forces, relationships, and outcomes of interactions within and between subsystems of social systems. The selection of mechanisms for the development of an innovation ecosystem therefore requires identifying the main agents, forces, relationships, and outcomes that result from interactions within and between subsystems; and then identifying the weakest parts and the forces, relationships, or outcomes that have the greatest impact on them. Consequently, the value chain management system approach needs to be understood both at the level of the ecosystem actors and at the level of the whole system.

3. Service management framework in an innovation ecosystem

One of the fundamental practices of operational management is the Toyota Production System (TPS), already mentioned, which has been the basis for many production management systems**. Figure 3** shows Liker's interpretation (Liker, 2004).

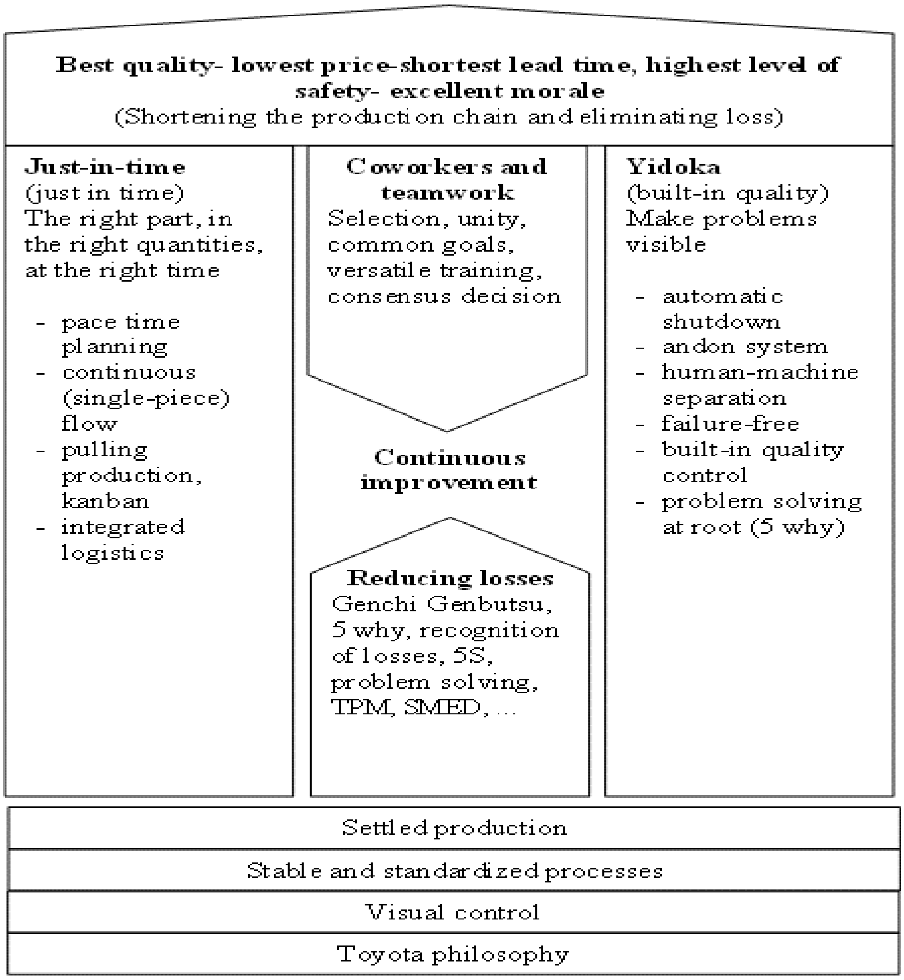


Figure 3. Toyota Production System (Liker, 2014)

It is easy to see that the objectives of the model can also be agreed for services. Quality assurance and continuous improvement are also essential components of service systems. In services, there is less material flow, less stock, and more user participation (co-creation) in the processes, more queues.

In the service domain, the number of similar models is much more limited, an example is shown in **Figure 4.**

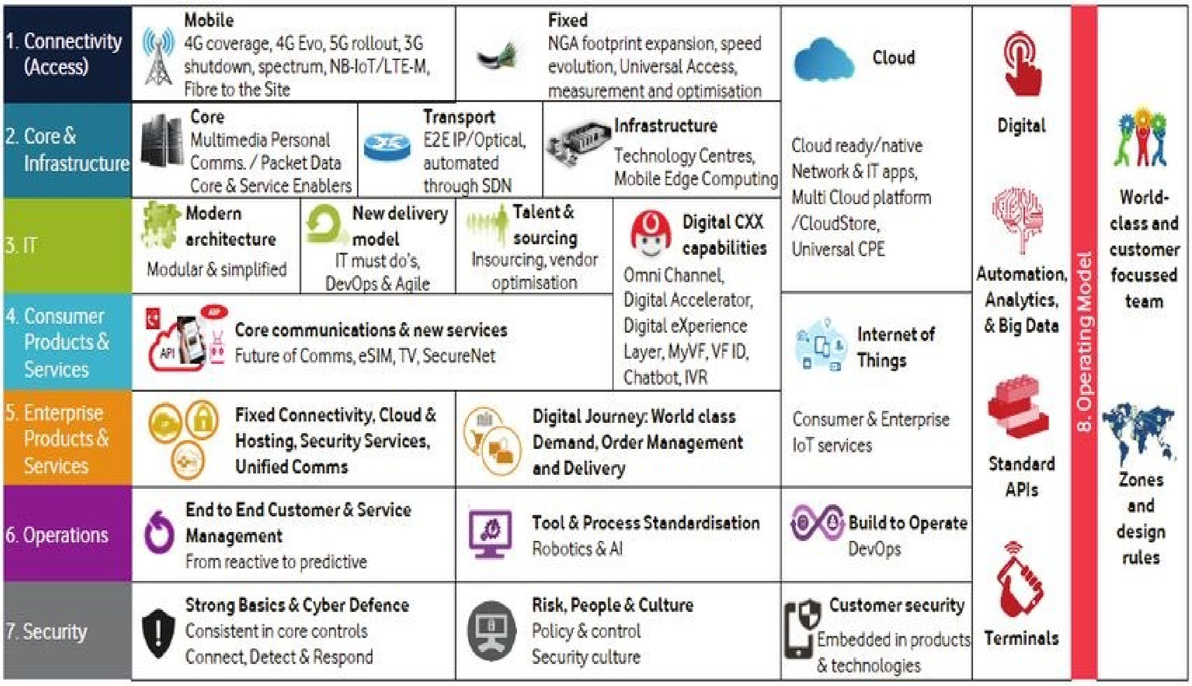


Figure 4. Service Management Model Vodafone (Kerr and Moloney, 2018)

The importance of collaboration is crucial within the innovation ecosystems. In the following, related research is referenced in view of the service management perspective.

Harmonious and complementary cooperation between actors is critical for the effectiveness and efficiency of the whole system. Identifying and investigating sources of inconsistency within the system is, therefore, an important area of research. Responses to the environment often evolve spontaneously from bottom-up interactions without central guidance. Advanced innovation ecosystems thus balance on the 'edge of chaos', where creativity and innovativeness are at their highest levels simultaneously (Mason, 2007).

What distinguishes ecosystems from purely market-based service structures is that the actors are bound together by certain interdependencies, for example, they all adhere to certain norms. In this sense, ecosystems are different from pure networks, even if the networks are formal or informal alliances between actors (Powell, 2003). In ecosystems, the customers must associate themselves with a group or platform to be able to take advantage of its specific benefits (Hagiu &Wright, 2015).

As Teece (2018) points out, to exploit opportunities for collaboration within the ecosystem, organizations should seek complementarity of purpose, but this can take several forms depending on the nature of the collaboration. Complementarity, a descriptive characteristic of the relationship between actors, can be used to clearly express the relationships between actors within an ecosystem. Hence, it is particularly important to identify and visualize the similarities or differences between the characteristics of the actors.

4. Specific case: ZalaZONE Science & Technology Park

4.1 Research problem discussed in the paper

One of the key benefits of an innovation ecosystem is the collaborative environment offered for its actors to operate in. As usual, cooperation needs a common language among the concerned parties and the opposite side, the identification of serious differences between actors might contribute to preparing and managing a collaborative culture. In the present analysis, the authors approach the topic from an operational management perspective and examine the actors of an ecosystem through the elements of a general service management framework model. Based on this, it is possible to point out differences through various factors in order to determine possible conflict sources. The aim of the study is to show a method for identification of potential points of inconsistency along the four groups of aspects as potential sources of barriers to collaboration. After literature review, the value system, the operational-business philosophy, the methods, and the objectives of a research and technology center are analyzed. The presented approach can serve as a general method for identifying inconsistencies in innovation ecosystems.

4.2 ZalaZONE Service Management System

The unique proposition of the ZalaZONE Automotive Proving Ground in Hungary is, that it not only offers the possibility to perform traditional vehicle dynamics tests, but also allows validation tests of automated, connected and autonomous (self-driving) vehicles, as well as electric vehicles. The first modules of the test track were already completed in 2019, and since then, the testing modules are available to customers. The 230 ha testing facility became completed in 2021, now it is in operational mode.

The ZalaZONE Science and Innovation Park is an innovation ecosystem around the proving ground aiming to create an environment that contributes to strengthening the translational impact of the test track. It is expected to result in the establishment of leading R&D and innovation companies, building on and collaborating with universities, research institutes and other service providers, and industrial companies that have established R&D bases locally. The ZalaZONE Research and Technology Center, as a knowledge hub and driver of the park, has been operative since 2019 and, through its tenant actors, offers in-vehicle measurements, simulation support, vehicle-level radar sensor testing, mechatronics, and engineering services.

Figure 5 summarizes the service management system model for the ZalaZONE Research and Technology Center, built on the theoretical considerations presented above, especially the model of Figures 1 and 2 and key findings of Chapter 3.

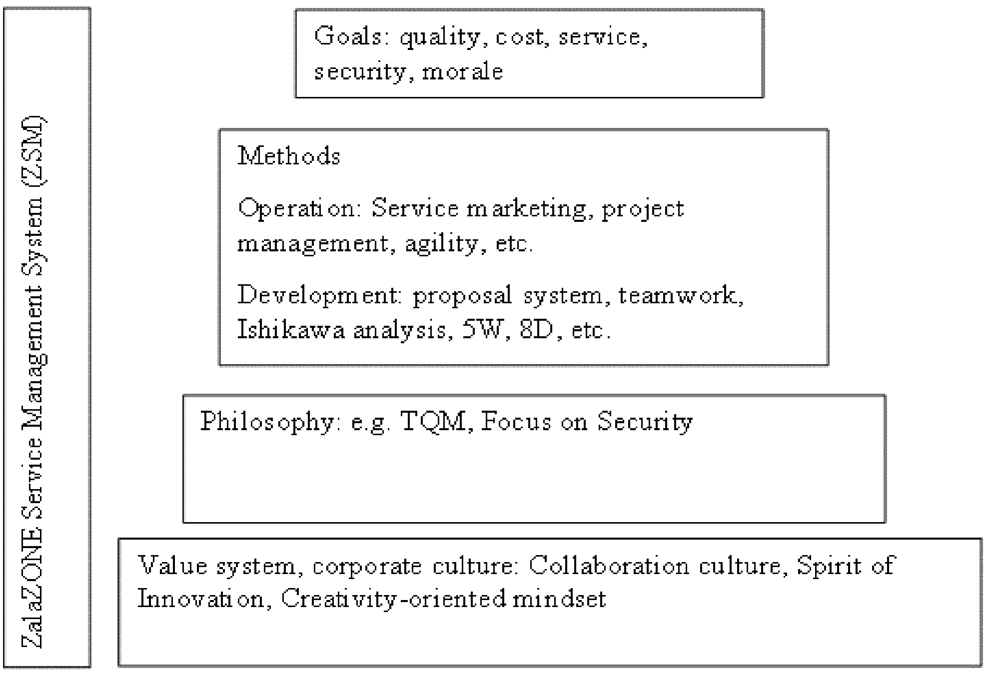


Figure 5. Service management system model for the ZalaZONE Research & Technology Center (own editing)

4.3 Structure of the ecosystem

The actors of the ZalaZONE Research and Technology Centre as an ecosystem are players from both the industry and the scientific field. The players are mentioned in an anonymous way, with identification numbers during the whole analysis.

- Univ_1: research group, whose main task is to support the research of headquarter university and its partners related to the use of proving ground and the practical validation of the specific developed concept supporting the testing methods of self-driving vehicles.
- Univ_2: a research group whose main tasks are to support the research of base university and its partners related to the use of proving ground and to develop and operate the university's industrial service site in Zalaegerszeg.
- Univ_3: is present in education in Zalaegerszeg and the region in cooperation with the ZalaZONE Research and Technology Center. The base university has been an active participant in the region's higher education activities in the field of engineering for decades.
- Serv_1: the R&D department of the ZalaZONE Automotive Proving Ground and the unit coordinating the research use of the test track.
- Serv_2: the unit coordinating the dual and trainee student base around the whole ecosystem and the student community connected to the Science and Innovation Park.
- Serv_3: contributes to the development and competitiveness of industrial enterprises, in particular mechanical engineering enterprises, by providing complex technical R&D services; provides physical solutions to complex industrial problems requiring innovative directions, broad perspectives, and often comprehensive analysis.
- Serv_4.: one of the few companies in the world to offer a contactless vehicle data reading and processing solution to customers, independent of vehicle manufacturers; their contactless sensor product is a unique method of connecting to the network of vehicles.
- Serv_5: is active in the manufacturing enterprise producing of components for production lines, the manufacturing of equipment for the transport and storage of components and finished products in factory areas, the manufacturing of components for the drive train family of agricultural machinery.
- Serv_6: provides consultancy, development, and service activities in the field of mechatronics for a wide range of industries, both domestic and foreign customers; contributes to the success of its partners through its innovation and consultancy activities.

The players make their own business or research activity for the specific target groups in line with the corporate policies. However, the environment of ZalaZONE Research & Technology Center as micro-ecosystem also offers and encourages possibilities of co-operation among these players. The nature of co-operation can be one-by-one, but can be also consortia-type, involving more organizations. The base co-operation level is the classic client-supplier relation, but in some cases partnership approach is also arising.

The methodology of the study builds on the model shown in Figure 5, with the main characteristics of the actors of the research center being analyzed on the basis of its elements.

4.4 Method of the analysis

The aim of the analysis is to examine the concept of the ZalaZONE Service Management System by evaluating the characteristics of the actors of the research and technology center as a specific “micro-ecosystem”. The research approach is built on the findings summarized in literature review, especially those of Smith (2017) and Smith (2019). Method-related questions also considered research findings shown in Chapter 3, especially Toyota value approach.

In the following, the content of the research is summarized.

Value system, corporate culture:

It is assumed that the value system of a company is derived from its ownership background. The organizational culture is different for an SME, a large enterprise, a university or a public operator. The study therefore examined the ownership background of the actors in the ecosystem.

Philosophy:

To position the actors in an innovation ecosystem, it is necessary to assess the characteristics of technology-intensive versus research-intensive organizations and, on this basis, infer the business and innovation philosophy of the actor. For this purpose, the so-called KIBS/NTBF evaluation method is used (Tóth-Háry, 2021), which classifies organizations into the category of R&D service provider or Knowledge Intensive Business Service (KIBS) or New Technology-based Firms (NTBF) based on the approach of (Xiuqin et al., 2018). Based on experiences and research, the operational and business philosophy of an R&D service provider, a knowledge-intensive business service provider, a new technology-based firm is significantly different.

Methods (operations and development):

Within this aspect, a survey of the management methods used could be carried out, however, the research center currently under study includes small organizations, many of them established in the near past, and such a survey would not show the real methodological background. At the same time, it makes sense to look at the systematic management of orders/projects, the orderliness of the area, and the control of financial processes in this type of company, and therefore specific aspects were taken into account when surveying organizations:

1. Business plan, strategic approach
2. Organizational structure
3. Systematic management methods for projects/orders
4. Territorial organization
5. Cost controlling methods
6. Understanding and commitment to the ecosystem
7. Contribution to the ecosystem
8. Definition of objectives

Objectives:

All organizations operate according to defined management objectives. The highest-level indicators are usually turnover, number of employees, profit, and equity. These provide a general way of looking at the actors in an ecosystem, in particular considering the trend of the indicators.

Data collection was made in two ways: through interviews with executive leaders of actors within ZalaZONE Research and Technology Center (see method any philosophy sections), and by evaluation and processing of publicly available company and operational data of the companies (see corporate and goals sections). The research involved 9 actors, out of the total 10 inside the research center in the analysis.

5. Discussion and results

Some introductory considerations are summarized here to prepare the interpretation of the survey results.

Value system, corporate culture:

Table 1 shows the results based on an analysis of the ownership of each organization (Organization size, public or private institution and R&D background), with an assessment on three variables. It can be seen that the ownership structure is diversified, reflected by the matrix. It can be seen that the ownership structure is diversified, SMEs appear in the ownership structure in a similar proportion as large companies. State and private ownership occurred in nearly 50% of the organizations examined. In the case of university actors, it can be observed that they are university-owned, while industrial organizations tend to obtain R&D support from industry/market actors.

Table 1. Ownership background of the examined organizations

Organization	Owner Size		Owner nature		R&D background	
	SME	Large organization	State background	Private property	University player	Industrial/market player
Univ_1		X	X		X	
Univ_2		X	X		X	
Univ_3		X	X		X	
Serv_1		X	X			X
Serv_2	X			X		X
Serv_3	X			X		X
Serv_4	X			X		X
Serv_5	X			X		X
Serv_6	X			X		X

Philosophy:

The assessment was carried out on the basis of the so-called KIBS/NTBF approach and shows the given profiles in Figure 6. It can be seen that each organization is a mixture of the three categories, but dominant characteristics can be identified on this basis case-by-case. The university actors are more open to new technologies and knowledge intensity, while the organizations are less oriented towards technology intensive and look for new technological solutions related to their scientific peers.

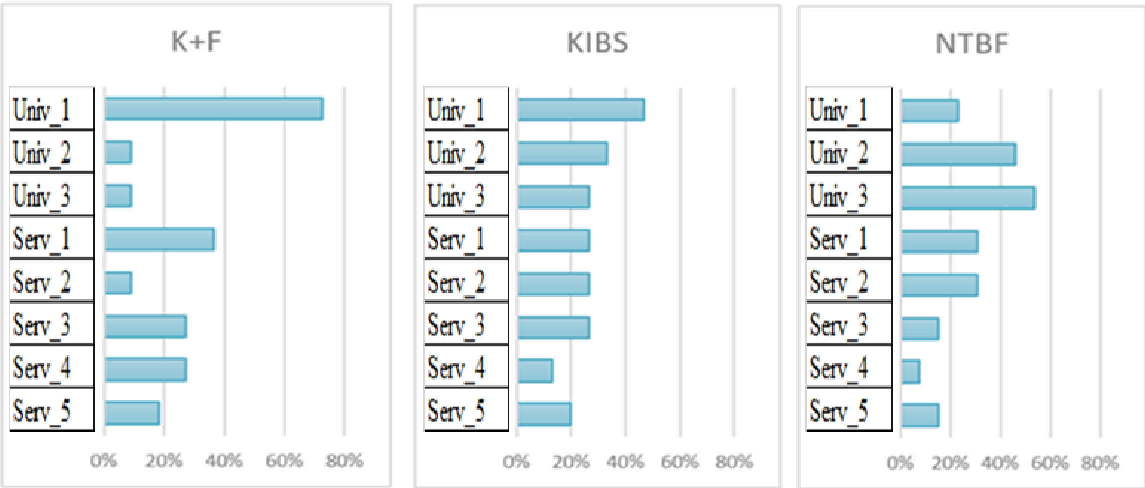


Fig 6. Nature of the examined organizations

Methods (operation and development):

Looking at each organization based on the seven criteria, the assessment in Table 2 was given on a scale of 1 to 4 (where: 1 uncharacteristic, 4 very typical). The results are scattered, with a dominant value 4 in many cases, which is a positive reflection of systematic operations. The seven criteria reflect the operational model approach of organizations (strategy, organization, methods, goals, etc.). The results show that all of the 7 criteria are considered very typical (4) by the respondents.

Table 2. Evaluation of the methods of the examined organizations

Players	Business plan, strategic approach	Organizational structure	Systematic management of projects/order	Area order	Cost controlling methods	How well he understands and how committed he is to the ecosystem	Contributing to the ecosystem	Set goals
Univ_1	1	3	4	3	3	3	3	4
Univ_2	4	4	4	4	3	4	4	4
Univ_3	1	1	1	1	1	2	2	2
Serv_1	2	3	4	3	3	3	4	4
Serv_2	3	4	3	2	2	4	4	4
Serv_3	4	4	4	3	3	4	3	4
Serv_4	1	2	2	2	2	2	2	2
Serv_5	2	3	4	3	3	4	3	4
Serv_6	2	2	3	3	3	3	3	4

Goals:

With regard to the main business and operational indicators, the absolute values in thousand HUF and trend direction (+/o/-) have also been taken into account, the results are shown in Table 3. Some of the actor is in growing or start-up phase, while others belong to a more mature mother organization or headquarters.

Table 3. Evaluation of **the** main management metrics of the examined organizations

Players	Number	Turnover	Result	Equity
Univ_1	10	80 000 000	0+	40 000 000
	o	+	o	+
Univ_2	20	105 000 000	0+	15 000 000
	+	+	o	+
Univ_3	2	3 000 000	0+	1 000 000
	o	o	o	o
Serv_1	5	30 000 000	1 000 000	1 000 000
	o	+	o	o
Serv_2	7	45 000 000	0+	60 000 000
	+	+	+	+
Serv_3	15	110 000 000	5 000 000	50 000 000
	o	+	+	o
Serv_4	3	455 932 000	20 857 000	210 792 000
	o	+	+	o
Serv_5	3	105 582 000	25 440 000	83 122 000
	o	o	+	+
Serv_6	2	5 120 000	19 000	3 676 000
	o	+	+	+

In order to identify potential points of inconsistency between the actors in the innovation ecosystem, the actors were examined pairwise, looking for significant points of differences in terms of values, philosophy, methods, and goals. Table 4 shows the basic theoretical approach of the study. It is assumed that the inconsistency, as a possible point of inhibition of cooperation, stems from the significant differences between the actors.

DOI: 10.6977/IJoSI.202406_8(2).0003
C. Toth, B. Fehervolgyi, et al. /Int. J. Systematic Innovation, 8(2), 31-43 (2024)

Table 4. Identification of potential inconsistencies between the examined organizations

Players	Univ_1	Univ_2	Univ_3	Serv_1	Serv_2	Serv_3	Serv_4	Serv_5	Serv_6
Univ_1									
Univ_2	ΔC_1								
	ΔM_1								
	ΔF_1								
	ΔY_1								
Univ_3	ΔC_2	ΔC_3							
	ΔM_2	ΔM_3							
	ΔF_2	ΔF_3							
	ΔY_2	$\Delta \acute{E}_3$							
Serv_1	ΔC_4	..	..						
	ΔM_4								
	ΔF_4								
	ΔY_4								
Serv_2	..	..	..	..					
Serv_3	..	..	..	..	..				
Serv_4	..	..	..	..	..	..			
Serv_5	..	..	..	..	..	..	..		
Serv_6	..	..	..	..	..	..	..	..	

When examining pairs, it is sufficient to analyze one side of the diagonal of the matrix as this way all combinations between actors in the innovation ecosystem could be considered.

In **Figure 7**, there is an illustration of the method along selected pairs as a concrete example, which, on this basis, is suitable for highlighting significant differences between any two actors in the innovation ecosystem.

Element	Characteristic	Univ_2	Serv_3	Variance	Comment
Values, culture: POINT OF INCONSISTENCY!	SME		1	x	Significant differences in ownership and the resulting value system!
	large organization	1		x	
	State background	1		x	
	Private property		1	x	
	University player	1		x	
	Industrial/market player		1	x	
Philosophy	R&D	1	3	x	Part of a difference in philosophy.
	KIBS	2	2		
	NTBF	3	1	x	
Methods	Business plan, strategic approach	4	4		Slight variance, no critical difference.
	Organizational structure	4	4		
	Systematic management of projects/orders	4	4		
	Area order	4	3	x	
	Cost controlling methods	4	3	x	
	How well he understands and how committed he is to the ecosystem	4	4		
	Contributing to the ecosystem	4	3	x	
	Objectives defined	4	4		
Goals	Number	1	1		There is a partial difference in goals, this is due to the organization.

Figure 7. Example - Identification of possible inconsistencies between two actors based on different characteristics

6. Conclusions and summary

The basic general conclusion of the research was that the methodology which had been developed based on the review of several related research findings is suitable for identification of apparent differences of characteristics of innovation ecosystem actors. This way, using the theoretical method presented and demonstrated in this paper is suitable for potential hampering factors in cooperation of actors as critical to the development of innovation ecosystems. In the following, the main findings derived from using the analysis method is summarized.

What we have examined?

In this research, the relationships between actors were examined in an innovation ecosystem from four perspectives: values and culture, philosophy, goals, and methods. The relationship of each actor in the ecosystem with each other actor was assessed along the four aspects, using data or rating scales or ratings for the given aspect.

What we found?

As a result of a survey of the actors in the ecosystem concerned, pairs of actors have been identified with extreme differences, like significant variation in the assessment of a particular aspect. The study showed that the pair with the most significant differences in each of the characteristics was a large university actor with a public background and a small market-based R&D company.

The novelty of the study is that it allows to systematically detect differences between actors in an innovation ecosystem along a relevant management aspect. Significant divergence between actors can lead to cooperation difficulties and is, therefore, a source of inconsistency between actors in terms of cooperation potential.

Theoretical relevance

The theoretical significance of the study presented in this article is that it offers a method for assessing the cooperation potential within an innovation ecosystem. The method presented in this paper illustrated the evaluation of a system of relationships between only two actors and four sets of criteria. With further research, the method could be further developed into a multi-stakeholder evaluation method or an evaluation method along additional criteria.

Practical relevance

Practical experience has shown that one of the sources of difficulties in cooperation is that actors do not find common ground, are too different, think significantly differently, and use different management approaches. The practical role of the method presented here is to point out possible sources of inconsistency that can make cooperation between actors difficult. It allows to visualization of critical aspects of cooperation, which provides a good basis for identifying and then avoiding or minimizing potential conflict situations.

Limitations of the study

The presented study was based on one selected case of an innovation ecosystem, with a limited number of actors. This limits the findings relevant to the type and nature of players from the point of view of cooperation behavior in an innovation ecosystem. Nevertheless, the method presented is suitable for the analysis of further cases, without any limitation.

Possibilities for further investigation

The method discussed in this paper has been developed for the analysis of pairs of actors in an innovation ecosystem. Further research can extend the methodology of evaluation into more-dimension comparisons, involving not only pairs but more actors into the comparison.

The scale and aspects of analysis can be also subject for further research, resulting in a more precise base and method for the comparison.

References

Autio, Erkko, & Thomas, Llewellyn D.W. (2014) Innovation Ecosystems: Implications for Innovation Management? The Oxford Handbook of Innovation Management, edited by Mark Dodgson, David Gann, and Nelson Phillips, Oxford University Press, 2014, pp. 204-288.

Chesbrough, Henry, Kim, Sabrina, & Alice, Alexandra. (2014). Chez Panisse: Building an Open Innovation Ecosystem. California Management Review, vol. 56, no. 4, 2014, pp. 144-171. https://doi.org/10.1525/cmr.2014.56.4.144.

Duncan, Robert B. (1972). Characteristics of Organizational Environments and Perceived Environmental Uncertainty. Administrative Science Quarterly, vol. 17, no. 3, 1972.

Fuchs, Christian. (2002). Concepts of Social Self-Organization. INTAS Project 'Human Strategies in Complexity', Research Paper 4, 2002. Retrieved from http://ssrn.com/abstract=385185.

Jucevicius, Giedrius, & Grumadaite, Kristina. (2014). Smart Development of Innovation Ecosystem. 19th International Scientific Conference; Economics and Management, ICEM 2014, 23-25 April 2014, Riga, Latvia.

Hagiu, Andrei, & Wright, Julian. (2015). Multi-Sided Platforms. International Journal of Industrial Organization, vol. 43, 2015, pp. 162–174.

Kerr, William R., & Moloney, Emer. (2018). Vodafone: Managing Advanced Technologies and Artificial Intelligence. Harvard Business School, 9-318-109, February 20, 2018.

Liker, Jeffrey K. (2004). The Toyota Way: 14 Management Principles from the World's Greatest Manufacturer. McGraw-Hill, 2004.

Mason, Roger B. (2007). The External Environment's Effect on Management and Strategy: A Complexity Theory Approach. Management Decision, vol. 45, 2007, pp. 10-28.

Murthy, V. K., & Krishnamurthy, E. V. (2003). Entropy and Smart Systems. International Journal of Smart Engineering System Design, vol. 5, 2003, pp. 481-490.

Powell, Walter W. (2003). Neither Market nor Hierarchy: Network Forms of Organization. The Sociology of Organizations: Classic, Contemporary and Critical Readings, edited by Michael J. Handel, Sage Publications, 2003, pp. 104-117.

Teece, David J. (2018). Profiting from Innovation in the Digital Economy: Standards, Complementary Assets, and Business Models in the Wireless World. Research Policy, 2018.

Toth, Csaba & Háry, Andrea. (2021). Evaluation Method for Actors in an Innovation Ecosystem. Hungarian Quality, vol. XXX, no. 1, 2021, pp. 5-12.

West, Joel & Wood, David. (2008). Creating and Evolving an Open Innovation Ecosystem: Lessons from Symbian Ltd. SSRN, 2008. Available at SSRN 1532926.

Xiquin, Liu, Gagliardi, Dimitri, & Miles, Ian. (2018). Innovation in R&D Firms: Evidence from the UK. Technology Analysis & Strategic Management, 2018.

DOI: 10.6977/IJoSI.202406_8(2).0004
M.J.M. Kamil, N.N. Samsuddin, et al./Int. J. Systematic Innovation, 8(2), 44-57 (2024)

The integration of Ergonomics Ergo-System Framework (EESF) with the product design process in the innovation ergonomic seating support for scoliosis patients

Muhammad Jameel Mohamed Kamil[1,2]*, Nazratul Nadiah Samsuddin[3], Mohd Najib Abdullah Sani[1,4], Amir Hassan Mohd Shah[1]
[1] Faculty of Applied and Creative Art, Universiti Malaysia Sarawak, Kota Samarahan, Sarawak, Malaysia
[2] Institute of Creative Arts and Technology, Universiti Malaysia Sarawak, Kota Samarahan,Sarawak, Malaysia
[3] Universiti Sains Malaysia, Gelugor, Penang, Malaysia
[4] University Industry Centre, Universiti Malaysia Sarawak, Kota Samarahan,Sarawak, Malaysia
* Corresponding author E-mail: mkmjameel@unimas.my
(Received 4 October 2023; Final version received 1 January 2024; Accepted 25 February 2024)

Abstract

Several researches in medical science have revealed that individuals who have scoliosis experience discomfort while sitting upright, leading to symptoms like leg pain, back pain, and claudication. These symptoms can limit their ability to perform certain tasks in the office. Thus, this paper utilized Ergonomics Ergo-System Framework (EESF) to design a innovative ergonomic seating support for scoliosis patients. Through the interview study conducted with a rehabilitation specialist, a physiotherapy expert, and three scoliosis patients in Malaysia, the EESF was integrated to identify patients design issues and needs. The result of solution components and design criteria obtained from the interview study highlights the parameters for the development of ergonomic seating support. The decision of innovative design of the ergonomic seating support incorporated the modular seating concept for office use, visually aesthetic with emotional design elements, and equipped with adjustable spinal support. To develop the semi-working ergonomic seating supporter concept model for future production, a design process was executed. It is hoped that the outcome of this study will contribute to demonstrating how the EESF can be utilized, integrated with the innovative product design process, and benefit scoliosis patients.

*Keywords: Ergonomics Ergo-System Framework, Design Thinking, Scoliosis, Erg*onomic, Product Design

1. Introduction

Scoliosis is a condition that occurs in mature patients with a spinal deformity where the Cobb angle in the coronal plane is greater than 10 degrees. Aebi (2005) has classified scoliosis into four major categories. The first type, as shown in **Figure 1**, is primary degenerative scoliosis, which is primarily caused by arthritis in the discs and/or facet joints. This leads to an asymmetrical impact on those structures and typically results in back pain indications. It frequently occurs with or without symptoms associated with spinal stenosis, both central and lateral stenosis. This curvature is referred to as "de novo" scoliosis (Benner & Ehni, 1979; Epstein et al., 1979; Fowles et al., 1978; Grubb et al., 1988; Grubb & Lipscomb, 1992; Korovessis et al., 1994; McKinley et al., 1977).

The second type of scoliosis, as depicted **in Figures 2, 3,** and **4,** is progressive idiopathic scoliosis that occurs during adulthood. The thoracic and/or lumbar spine are commonly affected by this scoliosis, which continues throughout adulthood. It frequently has a connection to secondary degeneration and/or imbalance (Kostuik & Bentivoglio, 1981; Ogilvie, 1992; Sponseller et al., 1987; Winter & Lonstein, 1983).

The third type of scoliosis, illustrated in Figure 5, is secondary degenerative scoliosis. It can develop as follows: (a) It may develop when a person has idiopathic, or another kind of scoliosis, or due to a pelvic obliquity caused by hip pathology, an imbalance in leg length or a lumbosacral transitional malformation. This scoliosis type o is mainly found in the thoracolumbar, lumbar, or lumbosacral spine. (b) Scoliosis can also be caused by metabolic bone disease, such as asymmetric, osteoporosis, arthritic disease, and/or spinal fractures (Bradford et al., 1999; Deyo et al., 1992; Healey & Lane, 1985; Robin et al., 1982; Velis et al., 1988)

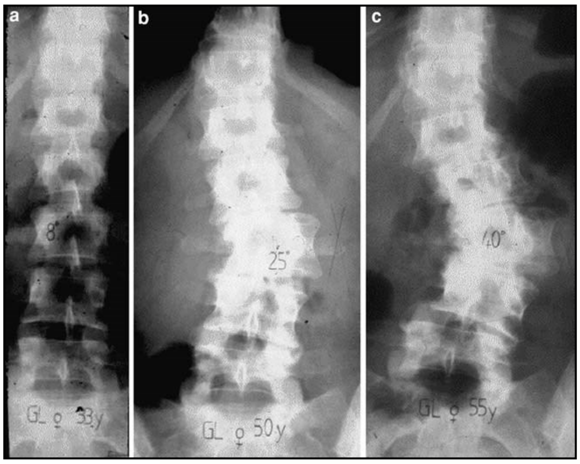


Figure 1. De novo scoliosis (type 1 adult scoliosis). **(a)** age 33 (8 degrees), **(b)** age 50 (25 degrees), and **(c)** age 55 (40 degrees), adopted from Aebi (2005).

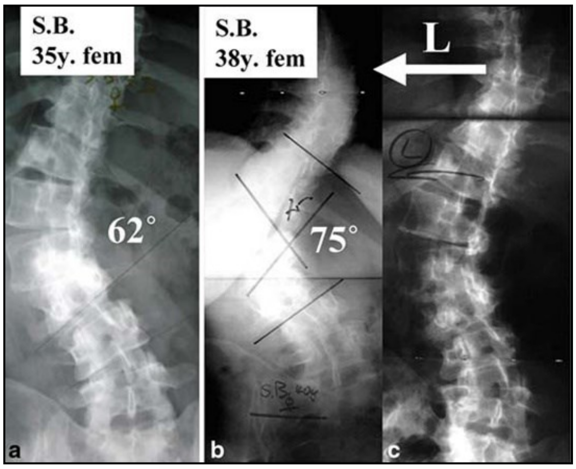


Figure 2. A young female with progressing idiopathic scoliosis occurred in adult life (type 2 scoliosis). **(a)** 62 degrees at age 35 **(b)** advanced to 75 degrees at age 38, and **(c)** left bending with minor correction, adopted from Aebi (2005).

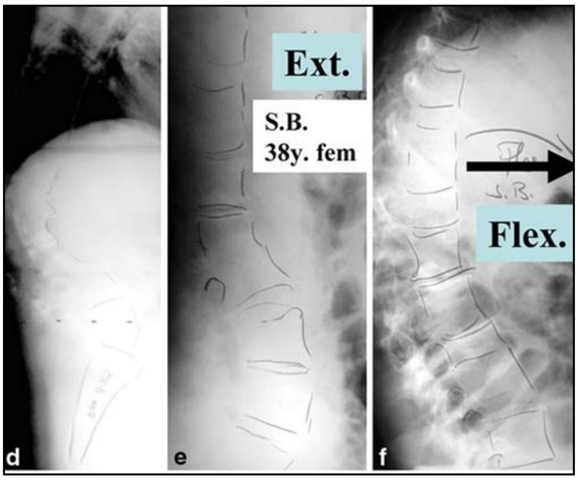


Figure 3. A young female with progressing idiopathic scoliosis occurred in adults. (type 2 scoliosis) **(d)** severe lumbar kyphosis; **(e)** partial extension correction; **(f)** thoracic spine flexion, adopted from Aebi (2005)

Figure 4. A young female with progressive idiopathic scoliosis occurred in adulthood (type 2). **(g) and (h)** 18 months post-operation, adopted from Aebi (2005).

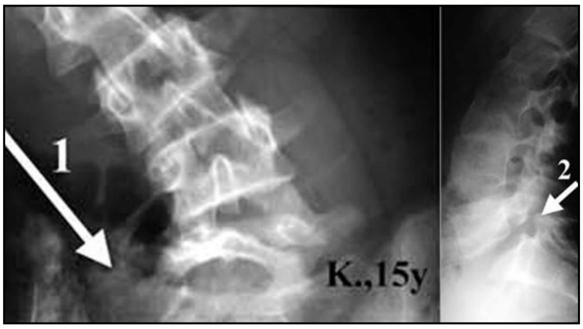


Figure 5. Scoliosis of type 3 in a female patient, age 25. Arrows **(1)** indicate a transitory abnormality while Arrows **(2)** indicate L5 spondylolysis, adopted from Aebi (2005).

Scoliosis may appear at any age and can either get worse or start to cause symptoms in adults. Alternatively, scoliosis can develop in adulthood without any prior history, referred to as "de novo" scoliosis. Aebi (2005) notes that the most common clinical groupings are secondary (type 3) and primary (type 1) degenerative adult scoliosis. Osteoporosis can exacerbate both types of scoliosis in older adults, including type 2 scoliosis. At some point, all three types of scoliosis can present as degenerative scoliosis, which is the primary form of adult scoliosis.

The exact cause of scoliosis with a primary location in the lumbar or thoracolumbar spine is difficult to identify, but once an asymmetric load or degeneration occurs, a predictable pathomorphology and pathomechanism can be observed, as noted by Aebi (2005). Asymmetric degeneration can lead to an increase in asymmetric load, which can cause the development of scoliosis and/or kyphosis as well as deformity. Osteoporosis, particularly in postmenopausal women, can also contribute to the progression of the curve. The facet joints, joint capsules, discs, and ligaments can all be affected and destroyed, resulting in mono or multisegmented instability, and eventually, spinal stenosis.

Ágústsson, Sveinsson, and Rodby-Bousquet (2017) suggest that scoliosis can be caused by the weakening of spinal muscles, leading to discomfort, deformity, and decreased cardio-respiratory function. Lephart and Kaplan (2015) assert that individuals with scoliosis may have difficulty sitting upright and may experience pain, potentially restricting their activities. Back pain is the most frequent indication, followed by leg pain and claudication, while neurological problems and concerns about appearance are rare. Once the muscle weakness is severe, the resulting deformity can be challenging to treat, making slowing the progression of the condition the most effective approach.

Seeger and Sutherland (1981) state that traditional wheelchair designs do not provide proper support to the spine due to the lack of stable pelvic position and resistance to sideways spine bending. Crytzer et al. (2016) found that the design of seating supports significantly affects seating comfort and functionality and lowers spinal strains and associated healthcare costs. Seeger and Sutherland (1981) hypothesized that custom-molded seating may improve sitting comfort and delay spinal curvature advancement in scoliosis patients, and aimed to develop low-cost, comfortable seating to aid spinal deformity treatment. The work on this subject has previously varied from merely cushioning the armrest to specially molded chairs to disperse force over the rib cage. Although the method was labor-intensive and therefore expensive, a variety of comfortable chairs were made by Seeger and Sutherland's (1981) early attempt at custom molding utilizing the bean bag expulsion and consolidation technique. In order to help correct spinal deformity, they set out to build a low-cost method of enabling comfortable seating. Utkan, Fredericks, and Butt (2011) conducted a study using the Scoliometer, an inclinometer that determines any trunk asymmetries or axial trunk inclination (ATI) in the torso flexion, to investigate the impact of self-selected back support on adults with scoliosis during seating. It was discovered that all respondents opted to pick support that was not uniform throughout the lower back based on the 35 diodes in the low back that they self-selected to adjust for their support needs. The study highlights the importance of further assessment of seating issues and ergonomic seating support design for adult scoliosis patients.

This research paper is focused on the integration of ergonomics EESF with the product design process in the innovation of ergonomic seating support for scoliosis patients. It highlights the importance of incorporating human factors in product design, which involves studying human behavior, identifying obstacles and expectations, and conducting research and development to develop innovative products that offer increased value to users. This approach is currently considered a crucial aspect of product design (Abdullah Sani et al., 2019; Chumiran et al., 2020; Kamil et al., 2018, 2019a, 2019b; Kamil & Abidin, 2013; Li & Mohamed Kamil, 2022; Mohamed Kamil et al., 2020; Mohamed Kamil, Ho Wan Ying, et al., 2022; Mohamed Kamil, Hua, et al., 2022; Mohamed Kamil & Abdullah Sani, 2021; Mohamed Kamil & Abidin, 2014; Mohamed Kamil & Shaukat, 2023; Mohamed Kamil & Zainal Abidin, 2014, 2015; Sani et al., 2020).

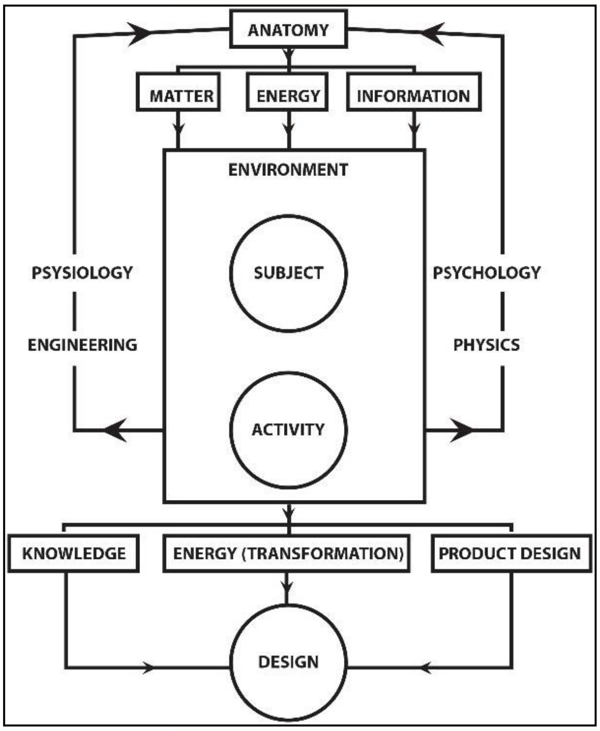


Figure 6. Scoliosis of type 3 in a female patient, age 25. Arrows **(1)** indicate a transitory abnormality while Arrows **(2)** indicate L5 spondylolysis, adopted from Aebi (2005).

The main objective of the study is to explore the potential for theoretical investigation that complements design practices, to create innovative product designs that meet the needs of users. As proposed by Bridger (2008), the EESF is typically employed to enhance system performance but has been adapted here for product design practice, specifically to develop an ergonomic seating supporter for scoliosis patients (see Figure 6). The framework consists of five elements drawn from the fields of ergonomics: anatomy, and engineering. physiology, psychology, and physics. The five elements interact with each other and the environment, with the synchronization of "people" and "machine" interactions forming the foundation of the framework to generate a specific output. The input of supplementary variables, material, design needs, and facts, varies depending on the stage of human factors study. In this study, the framework is employed to support designers' design thinking from the initial levels of empathizing with the user's needs, through brainstorming and ideation, to prototyping and testing. The user's synchronization with the context is the foundation of the system. Understanding the user's condition or circumstance in a particular context or location is essential to comprehending the relationship. The subject's condition or circumstance will provide insight into their thoughts on the physics of their environment and how it impacts their psychology and needs. Academically, this research also aims to broaden the understanding of the importance of ergonomics and design thinking and to present the product design process. It is hoped to broaden knowledge and motivate future investigation in design research by embracing cross-disciplinary studies with relevance to physiology.

2. Methodology

In this study, the development of an ergonomic seating supporter for scoliosis patients was conducted based on previous research that integrated ergonomics, behavior, and product design needs (Bruno et al., 2016; Chen & Chu, 2012; Demirbilek & Sener, 2003; Kamil & Abidin, 2013; Matos et al., 2014; Mohamed Kamil et al., 2020; Mohamed Kamil, Hua, et al., 2022; Sani et al., 2020; Schütte, 2005). The main objective of the study was to identify the design elements needed by scoliosis patients, incorporating the ideal design feature for the ergonomic seating supporter, to improve their physical comfort while sitting. To achieve this, a semi-structured interview was held with three scoliosis patients, a rehabilitation expert, and a physiotherapy expert, with each interview session lasting 45 minutes at the Advanced Medical and Dental Institute in Penang, Malaysia. The five sets of ergonomics scientific elements - physiology, anatomy, physics, engineering, and psychology, were proposed in the ergonomics ergo system framework and served as the basis for the construction of the interview questions. For example, the physiology expert was interviewed to obtain a professional opinion on issues related to scoliosis, such as its symptoms and diagnosis (anatomy), its impact on physical well-being (physiology), its impact on patients' emotional state (psychology), and available treatment options (physiology). The rehabilitation expert was interviewed to gain a deeper understanding of the rehabilitation technology available for scoliosis (engineering) and the variation of physical treatment (physics), while the interview with scoliosis patients aimed to assess design requirements based on their difficulties and psychological responses to existing ergonomic seating (psychology and physics).

2.1 Phase 1: Assessing the design needs.

In order to establish a clear design direction, the design thinking and the EESF had to be integrated, and the interview analysis played a significant role in the design process. During the first phase of the interview data analysis, the focus was on gaining a better understanding of the respondents, their challenges, and design requirements. In this research, the EESF forms the basis of the researcher's cognitive process, ensuring alignment between the respondents and their contextual surroundings. Employing this framework, the study seeks to investigate the circumstances and conditions of participants, offering insights into how the environment impacts their psychology and requirements (Mohamed Kamil & Abdullah Sani, 2023). This all-encompassing approach considers the dynamic interplay among anatomy, engineering principles, physiological aspects, psychological factors, and the laws of physics, fostering an in-depth comprehension of the experiences of individuals with scoliosis. For instance, in the study of activities leading to back discomfort among scoliosis patients, the anatomical aspect of the EESF plays a pivotal role in understanding the physical configuration of scoliosis patients, particularly the curvature of the spine and its influence on posture and movement. Simultaneously, the physiological component of the ESSF is imperative for recognizing how the physiological aspects of patients' conditions impact bodily functions and comfort, encompassing the evaluation of muscle activity, blood flow, and respiratory patterns. This gathered information is then utilized to customize the design to accommodate the physiological variations associated with scoliosis.

The interview analysis followed the three coding steps described by Creswell (2009) and Saldaña (2009), including open coding, axial coding, and selective coding, to systematically analyze and organize the transcriptions of the interview data into categories of information. In a study to identify activities that may have caused back discomfort among the participants, the researcher employed a method known as open coding, which involves the identification of descriptive labels or speech analysis features from the respondents' utterance. The components of the respondents' speech were then separated out and categorised by the researcher, as indicated in Table 1. In order to create axial codes, which are more conceptual categories, the resultant open codes were further abstracted. Through selective coding, comparable coded data were grouped into conceptual categories that were derived from the open codes. The axial codes were adjusted to achieve the best match, and more than one axial code may have been created during this process. Additionally, data that was "divided" or "fractured" during the open coding process was reconstructed. The axis represents a category that was created from open coding at this level, and identifying these dimensions and organizing the available codes along them is a primary objective of early coding. For instance, based on their connections to one another, the open codes shown in Table 1 were given new names and rearranged. The researcher might have to repeat the process and recode the data after choosing a category or dimension depending on the newly developing notion that is encapsulated in the category or dimension. Muller and Kogan (2010) suggest that selecting which codes to develop further requires a choice of issues to research. Selective coding involves extracting data by examining the links between the groups created by axial coding (Creswell, 2009). The chosen coding only retains variables that are applicable and relevant to the key variables of the procedure, in order to produce explicit information. The core category, or axial coding, was identified and then classified and recoded as selected codes to provide a clear representation of the information. This process may need to be repeated several times to establish the relationship between the codes and develop the most plausible explanation.

Table 1. Sample of coding on respondents' activities that may have caused back discomfort.

Index	Respondent 1	Respondent 2	Respondent 3
Protocol Time	13:30	15:12	11:45
Transcriptions	"...I often feel back discomfort when I handle big goods and spend a lot of time standing, walking, or even sitting... My waist carries a lot of weight..."	"It usually appears to me that doing a lot of work makes my body weak and hurts my back..."	"…I don't think I can stand or walk for long periods of time without my back hurting..."
Attributes	1. Lifting heavy objects 2. Spending a lot of time standing, walking and sitting	1. Doing a lot of work	1. Standing for a long periods of time 2. Walking for a long period of time
Open Codes: Categories of information	Handling a lot of weight for an extended period of time including standing, walking, and sitting became a burden for the waist and resulted in back discomfort.	Doing a lot of work caused back pain.	Walking and standing for a long period of time caused the back pain.
Axial Codes	Scoliosis patients feel the back pain as a result of carrying a lot of weight, standing, walking, and sitting for a lengthy period of time.	Scoliosis patients feel back pain when they do a lot of work.	Scoliosis patients feel back pain from walking or standing for long periods of time.
Selective Codes	Carrying a lot of weight repeatedly including walking, standing, and sitting for a lengthy period of time causes back pain to scoliosis patients.		

3. Results

In this study, the coding technique used to analyze interview data started with empathizing with the situation that was being investigated. The study evaluated design requirements for scoliosis patients by considering five elements of ergonomics science: physiology, psychology, physics, anatomy, and engineering, within the ergonomics ergo system framework. During the interview, respondents provided information about the state or status of scoliosis patients, specifically how their circumstances and environment affect their needs. By understanding the anatomical and physiological requirements, it was possible to identify the significant design features and facts that could be improved further in the ergonomic seating supporter design process. The results of the interview were summarized into three descriptions of design needs and solution components, as shown in **Table 2**.

Table 2. Sample of coding on respondents' activities that may have caused back discomfort.

Descriptions of Design Needs	Solution Components
Patients sit in their office for half of the day. Therefore, the design of the ergonomic sitting should be modular and compatible with standard office chair designs.	Modular seating design for office users.
Most ergonomic seating supporter already on the market was poorly designed and gave the appearance of having health issues, which made patients feel less confident. Therefore, the aesthetic component of the ergonomic design should aid in regaining the confidence of patients.	Visually aesthetic design
Each patient has a unique spinal issue and curvature. Hence, ergonomic sitting should be flexible to accommodate spinal conditions, especially for an extended period of time of sitting.	Adjustable support

3.1 Phase 2: Generating design ideations.

The three descriptions of design needs and solution components were previously developed as a result of interview analysis. While this is happening, the next process involves generating design criteria for the ergonomic seating supporter using the three elements of solutions (see **Table 3**).

Table 3. Sample of coding on respondents' activities that may have caused back discomfort.

Design Criteria	Descriptions
Modularity	The ergonomic seating supporter would serve as a modular supporter that should be compatible with a variety of office seat designs.
Emotional element	The ergonomic seating supporter should boost the patient's sense of confidence overall.
Adjustable spinal support	Longer periods of comfortable sitting should be possible with ergonomic seating supporter. The ergonomic seating supporter should be assistive to reduce spinal dullness and stress.

Based on the stated descriptions of design needs, the modular concept, emotional element, and adjustable spinal support will be incorporated into the ergonomic seating supporter design. The ergonomic seating supporter is intended to be created as a modular supporter that can work with different seat designs. This is to ensure that potential users who spend a lot of time sitting at their desks can use products that complement different office chair designs. Additionally, it is believed that including an emotional component in the design will increase the patient's confidence. As outlined in the EESF, the psychological aspect is integrated during the study to comprehend the mental and emotional aspects of living as scoliosis patients, and how these factors influence their perceptions of comfort and discomfort. This knowledge contributes to the development of a seating supporter that addresses not only physical but also psychological well-being. Hence, the design's improved aesthetics would make potential users feel emotionally comfortable using the product. Aligned with the physics component within the EESF, the design will integrate adjustable spinal support features to provide flexibility and adaptability, catering to the unique spinal conditions and curvature exhibited by each scoliosis patient. This strategic incorporation is intended to mitigate spinal tension and alleviate the dullness associated with extended periods of sitting, thereby enhancing the product's effectiveness in addressing the specific needs of users.

Then, a sketching activity (Figure 7) was conducted to initiate the design ideation. With the term "idea" referring to a core thought that might be visual, physical, or abstract, design ideation may be characterized as the process of producing and exchanging ideas. Sketching, which has long been recognized as a crucial conceptual tool in this process, may help to fully comprehend the visual structure and composition of form design, as well as how form aesthetics operate and how form ingredients are organized. Components made from design requirements were utilized to visualize various stages of the ergonomic seating supporter development.

Figure 7. Design ideation process.

3.2 Phase 3: Model making process.

As illustrated in Figure 8, using the Autodesk Inventor 3D Design software, the result of the sketching process was transformed into a three-dimensional (3D) design. Over time, 3D modelling design software has demonstrated its ability to speed up the design process, especially in terms of effectiveness, job quality, and the final product. A realistic enhancement was made to the design's size and visual qualities (Mohamed Kamil & Abdullah Sani, 2020; Zhuopeng et al., 2023). The 3D design outcome makes it simpler to comprehend all aspects of the ergonomic sitting supporter design, including features, colors, and product measurements.

Figure 8. Three-dimensional (3D) design development.

In this phase, the engineering aspect of the EESF is utilized during the model-making process to construct design solutions capable of tackling the challenges presented by scoliosis. This involves a comprehensive consideration of the structural elements and material properties inherent in seating supporters. The envisioned design outcome aims to furnish substantial support, ensuring comfort, and facilitating the promotion of correct spinal alignment. The model-making process was initiated after the completion of 3D development. In this process, the research team can ensure that a concept is viable by creating a model to show how the real product would look. This required using a 3D printer called an Ender using the created 3D files. Throughout the procedure, the Ender 3D printer's Polylactic Acid (PLA) filament spool was inserted and fuelled directly into the head for extrusion to the printer's nozzle (see Figure 9). The motor then enables the filament to melt and pushes it through the 0.4mm printer nozzle after bringing it to the necessary temperature (approximately 200–210 °C). The extrusion nozzle moves in accordance with the mapped coordinates, causing the blackened material to harden on the plate.

Figure 9. 3D printing process and the printed outcome.

Then, a metal structure was fabricated, the spinal support adjuster was installed, and memory foam upholstery was completed (see Figure 10 and Figure 11). The technical elements of the model were continuously investigated throughout the process to be certain that all flaws in the design were corrected. The limitations of the ergonomic seating supporter and what actual users would behave, believe, and perceive when using the final design were preliminarily identified during this stage.

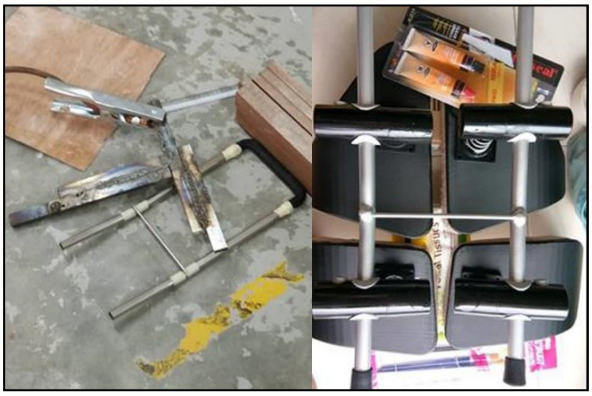


Figure 10. The fabrication of metal structure, and the installation of the spinal support adjuster.

Figure 11. The installation of memory foam upholstery.

After the serial iteration processes, which involve numerous adjustments to match the appropriate comfort, the final semi-working model is finished (see Figure 12). The aesthetic characteristics that distinguish the current ergonomic chair design trend including the practical issues underlining how possible users would act, think, and feel when handling the final product are among the most significant qualities of the semi-working model.

Figure 12. The final semi-working prototype.

4. Discussion

In this study, the EESF was utilized to incorporate the five sets of ergonomics science elements, including physiology, psychology, physics, anatomy, and engineering, which are crucial in addressing the specific requirements of scoliosis patients. The integration of EESF served as a design model that guided the research process through conducting a semi-structured interview study with rehabilitation experts, physiotherapy experts, and scoliosis patients. The interview data were analyzed using a three-step coding process, including open coding, axial coding, and selective coding. Open coding involves creating descriptive labels or speech analysis features to categorize the interview data. Axial coding was then used to create more abstract conceptual categories based on the open codes. Finally, selective coding involved sorting and relabeling the coded data to identify the design needs and solution components. Through the coding analysis of the interview data, it was found that extended periods of sitting can have an adverse effect on the comfort, posture, and overall well-being of scoliosis patients. Especially in an office environment, patients spend roughly 8 hours a day. The design of ergonomic seating should be modular and compatible with standard office chair designs to ensure that the ergonomic seating can seamlessly integrate into typical office environments without the need for significant changes or adaptations. Patients should be able to integrate their standard office chairs with these ergonomic alternatives easily. Hence, a modular seating design for office use is suggested as part of the solution component. In addition, the interview data also underscores the importance of the aesthetic component in the design of ergonomic seating supporters, particularly for patients with scoliosis. The data outcome suggests that many existing ergonomic seating options on the market are poorly designed and may give off an impression of being unattractive or unappealing, which can negatively impact the confidence of scoliosis patients. According to the interview, unattractive or poorly designed seating options make patients feel self-conscious about their health issues. Particularly for individuals with visible conditions like scoliosis, the seating may draw attention to their condition in an unflattering way. The aesthetic component of ergonomic design should play a role in regaining the confidence of patients. The visual appeal of the seating is not just about aesthetics for the sake of it; rather, it is a means to enhance the psychological well-being of patients. Therefore, a visually aesthetic design is suggested as a solution component as well. Furthermore, the outcome of the interview data also highlights the importance of flexibility and adjustability in the design of ergonomic seating, particularly for scoliosis patients with unique spinal issues and varying degrees of curvature. Since each patient's spinal condition is unique, the ergonomic seating should be adaptable to accommodate these conditions, especially during extended periods of sitting. An adjustable support allows scoliosis patients to personalize their seating experience. They can fine-tune the chair to align with their unique spinal curvature, providing optimal comfort and support. In detail, the ability to adjust the seating promotes better posture and spinal alignment, reducing the risk of discomfort and pain associated with prolonged sitting. It can also help alleviate pressure points and distribute body weight more evenly. Due to that, adjustable support is also suggested as a component of the solution. Overall, the research process involved assessing the design needs for the ergonomic seating support through interviews and coding analysis, guided by the EESF. This procedure provided valuable insights into the requirements of scoliosis patients, which informed the subsequent design and development phases of the study.

Once the description of the design need was obtained, the generation of design ideations for the ergonomic seating support was conducted. The process involved transforming the design criteria derived from the interview analysis into tangible design concepts. To initiate the design ideation process, a sketching activity was employed, allowing for the visualization of form, structure, aesthetics, and composition of the intended ergonomic seating support. The sketch development was based on the design criteria and aimed to explore various possibilities and variations for ergonomic seating support. This involved the variations of gestalt form of the intended ergonomic seating support, variations of the adjustable support mechanism, and variations color of memory foam upholstery. The output of the sketching activity was then translated into 3D designs using Autodesk Inventor 3D Design software. It enables our research team to construct a more realistic representation of the gestalt form of intended ergonomic seating support, adjustable support mechanism, and color variations of memory foam upholster. This process facilitates a better understanding of its dimensions, features, colors, and overall aesthetics of the product. In addition, the 3D design process also enables our research team to continuously refine and iterate the design ideations to ensure they meet the specific requirements of scoliosis patients. Feedback and input from the research team, experts, and potential users of the ergonomic seating support were incorporated into the iterative process. Overall, the process of generating design ideations was crucial in exploring different design possibilities and refining the concepts for ergonomic seating support.

Once the outcome of generating design ideations was obtained, the model-making process was conducted to create a physical representation of the ergonomic seating support design. This enables our research team to ensure the viability of the design concept and provide a tangible visualization of how the final product would look. The model-making process involved the use of an Ender 3D printer and Polylactic Acid (PLA) filament. Our research team utilized the generated 3D files to guide the printing process. During the printing process, the PLA filament was inserted into the 3D printer and fed into the extrusion head assembly, where it was melted and pushed through the printer nozzle. The extrusion nozzle followed the designated coordinates, allowing the material to solidify and form the desired shape on the printing plate. After the 3D printing process, a metal structure was fabricated, and the spinal support adjuster was installed. Additionally, memory foam upholstery was completed to enhance the comfort of the seating support. Throughout the model-making process, continuous investigations of the technical features of the model were conducted to address any design issues. The iterative nature of the model-making process allowed for adjustments and refinements to be made based on the feedback received and the identified limitations of the ergonomic seating support. This iterative approach ensured that the final model met the necessary comfort and functional requirements for potential users. The final semi-working model was achieved after several iterations, incorporating alterations to optimize user comfort. The model showcased the visual aspects that distinguished the ergonomic seating support design and demonstrated how potential users would interact with the product. Overall, the model making process played a crucial role in validating the design concept and refining the ergonomic seating support for scoliosis patients. It provided valuable insights into the technical feasibility and user experience of the design, paving the way for further improvements and the eventual development of a functional and effective product.

Figure 13. The panel design.

5. Conclusion

This research has successfully developed Scoolis, an ergonomic seating support as its design proposal to provide sitting comfort by reducing spinal dullness, and stress due to prolonged sitting among scoliosis patients. In accordance with the EESF, the five sets of ergonomics science elements (physiology, psychology, physics, anatomy, and engineering) were investigated through interview sessions with a rehabilitation expert, a physiotherapy expert, and three scoliosis patients. The results of the interview study provided three descriptions of design requirements, each of which covered components of ergonomics science. Before the three descriptions of design criteria (modularity, emotional element, and adjustable spinal support) were successfully attained, the solution components to match the descriptions of design needs were derived. Through the design process, sketching and 3D modeling techniques are employed to explore various possibilities and refine the Scoolis design concepts. The process highlights the importance of visualization and conceptualization in the design process. Followed by model making process, the physical representation of Scoolis was created using 3D printing technology, metal structure, and memory foam upholstery. The iterative nature of this process allows for continuous refinement and improvement of the design, taking into account technical features. The final semi-working model of Scoolis demonstrates the visual aspects and functional considerations of the design, providing valuable insights into user behavior and comfort. In the future, Scoolis might be enhanced and manufactured in huge volumes. Implementing the suggested design criteria will help with this. More crucially, the suggested design would enable us to promote the development for health and wellbeing. The drawback of this study is that more user testing and product performance assessment will soon be required to fully assess the applicability of the recommended ergonomic seating support.

Acknowledgement

Scoolis is patented with the copyright number AR2020004966. The research was supported by Faculty of Applied and Creative Arts (FACA), Universiti Malaysia Sarawak (UNIMAS) under the grant Kursi Petronas-P.Ramlee F03/PRC/2171/2021.

References

Abdullah Sani, M.N. et al. (2019). The Assessment of the Clubfoot Children's Orthotic Need for the Development of the Foot Abduction Orthosis (FAO) Prototype Design, International Journal of Advances in Science Engineering and Technology, 7(1), 20–24.

Aebi, M. (2005). The adult scoliosis, European Spine Journal, 14(10), 925–948.

Ágústsson, A., Sveinsson, Þ. & Rodby-Bousquet, E. (2017). The effect of asymmetrical limited hip flexion on seating posture, scoliosis and windswept hip distortion, Research in Developmental Disabilities, 71,18–23.

Benner, B. & Ehni, G. (1979). Degenerative lumbar scoliosis, Spine, 4(6), 548–552.

Bradford, D.S., Tay, B.K.B. & Hu, S.S. (1999). Adult scoliosis: surgical indications, operative management, complications, and outcomes, Spine, 24(24), 2617.

Bridger, R. (2008). Introduction to Ergonomics, Boca Raton, Crc Press.

Bruno, S. et al. (2016). The conceptual design of a mechatronic system to handle bedridden elderly individuals, Sensors, 16(5), 1–11.

Chen, L.C. & Chu, P.Y. (2012). Developing the index for product design communication and evaluation from emotional perspectives, Expert Systems with Applications, 39(2), 2011–2020.

Chumiran, M.H., Abidin, S.Z. & Kamil, M.J.M. (2020). Pre post observation research fosters a preliminary study in product form identity, Proceedings of the 22nd International Conference on Engineering and Product Design Education E&PDE 2020, 1, 1–6.

Creswell, J.W. (2009). Research Design: Quantitative, Qualitative, and Mixed Methods Approaches, SAGE Publications, Inc.

Crytzer, T.M. et al. (2016). Identifying characteristic back shapes from anatomical scans of wheelchair users to improve seating design, Medical Engineering and Physics, 38(9), 999–1007.

Demirbilek, O. & Sener, B. (2003). Product design, semantics and emotional response, Ergonomics, 46(13–14),1346–1360.

Deyo, R.A. et al. (1992). Morbidity and mortality in association with operations on the lumbar spine. The influence of age, diagnosis, and procedure, The Journal of bone and joint surgery, 74(4), 536–543.

Epstein, J.A., Epstein, B.S. & Jones, M.D. (1979). Symptomatic lumbar scoliosis with degenerative changes in the elderly, Spine, 4(6), 542–547.

Fowles, J. V et al. (1978). Untreated scoliosis in the adult, Clinical orthopaedics and related research, 134,212–217.

Grubb, S.A. & Lipscomb, H.J. (1992). Diagnostic findings in painful adult scoliosis, Spine, 17(5), 518–527.

Grubb, S.A., Lipscomb, H.J. & Coonrad, R.W. (1988). Degenerative adult-onset scoliosis, Spine, 13(3), 241–245.

Healey, J.H. & Lane, J.M. (1985). Structural scoliosis in osteoporotic women, Clinical orthopaedics and related research, 195, 216–223.

Kamil, M.J.M. & Abidin, S.Z. (2013). Unconscious Human Behavior at Visceral Level of Emotional Design, Procedia - Social and Behavioral Sciences, 105, 149–161.

Kamil, M.J.M, Abidin, S.Z. & Hassan, O.H. (2019a). Assessing Designers' Perception, Analysis, and Reflective Using Verbal Protocol Analysis, Chakrabarti, A. (ed.) Research into Design for a Connected World, Singapore, Springer Singapore, 51–61.

Kamil, M.J.M., Abidin, S.Z. & Hassan, O.H. (2019b). Assessing the Attributes of Unconscious Interaction Between Human Cognition and Behavior, In Everyday Product Using Image-Based Research Analysis, Chakrabarti, A. (ed.) Research into Design for a Connected World, Singapore, Springer Singapore, 63–73.

Kamil, M.J.M., Zainal Abidin, S. & Hasdinor Hassan, Os. (2018). The Investigation of Designers' Reflective Practice Activity Using Verbal Protocol, International Conference on Engineering and Product Design Education 6 & 7 September 2018, Dyson School of Design Engineering, Imperial College, London, United Kingdom, 363–368.

Korovessis, P. et al. (1994). Adult idiopathic lumbar scoliosis. A formula for prediction of progression and review of the literature, Spine, 19(17), 1926–1932.

Kostuik, J.P. & Bentivoglio, J. (1981). The incidence of low-back pain in adult scoliosis, Spine, 6(3), 268–273.

Lephart, K. & Kaplan, S.L. (2015). Two Seating Systems Effects on an Adolescent with Cerebral Palsy and Severe Scoliosis, Pediatric Physical Therapy, 27(3), 258–266.

Li, Z. & Mohamed, M.J. Kamil (2022). Research on the design of Chaoshan intelligent tableware based on digital image processing technology, CIBDA 2022 3rd International Conference on Computer Information and Big Data Applications, 626–630.

Matos, D. et al. (2014). Contribution of Design in the Developmental Process of External Prosthetic Medical Devices, Proceedings of the 5th International Conference on Applied Human Factors and Ergonomics AHFE 2014, Poland 19-23 July 2014, 2482–2487.

McKinley, L.M., Gaines, R.W. & Leatherman, K.D. (1977). Adult scoliosis: recognition and treatment, The Journal of the Kentucky Medical Association, 75(5), 235–238.

Mohamed, M.J. Kamil & Abdullah, M.N. Sani (2021). The Challenges and Initiatives of Teaching Product Design's Course Online During the COVID-19 Pandemic in Malaysia, Asia Pacific Journal of Educators and Education, 36(1), 113–133.

Mohamed, M. J. Kamil, & Abdullah, M. N. Sani (2023). Re-evaluation of the Cerebral Palsy ' s orthotic need in Adaptive Seating Orthosis (ASO) design, Journal of Graphic Engineering and Design, 14(4), 13–23.

Mohamed, M.J. Kamil & Abidin, S.Z. (2014). The Value of Unconscious Human Behavior in Product Design Innovation, 2nd International Conference on Technology, Informatics, Management, Engineering & Environment Bandung, Indonesia, 123–127.

Mohamed, M.J. Kamil, Ho, G. Wan Ying & Abdullah, M.N. Sani (2022). Product design activity as a process to develop a therapeutic toy for self-managed depression among adolescents, Journal of Graphic Engineering and Design, 13(4), 5–12.

Mohamed, M.J. Kamil, Hua, C.E. & Abdullah, M.Na. Sani (2022). Adaptation of smart-object dimensions in the product design process to reduce household food waste, Journal of Graphic Engineering and Design, 13(3), 5–17.

Mohamed, M.J. Kamil, Li Shi, S.M. & Abdullah Sani, M.N. (2020). Re-assessing the Design Needs of Trans-Radial Amputees in Product Design Innovation, Wacana Seni Journal of Arts Discourse, 19, 61–71.

Mohamed, M.J. Kamil & Shaukat, S.A. (2023) 'The implementation of polycaprolactone (PCL) as an eco-friendly material in toy design development', Journal of Graphic Engineering and Design, 14(1).

Mohamed, M.J. Kamil & Zainal, S. Abidin (2014). Unconscious Human Behaviour in Product Design: Designers' Perception, Analysis, and Reflection, 1st International Conference on Creative Media, Design and Technology, REKA2014, 109–114.

Mohamed, M.J. Kamil & Zainal, S. Abidin (2015). Unconscious Interaction Between Human Cognition and Behaviour in Everyday Product: A Study of Product Form Entities Through Freehand Sketching Using Design Syntactic Analysis, International Conference on Engineering and Product Design Education, Loughborough University, Design School, Loughborough, UK, 369–374.

Muller, M.J. and Kogan, S. (2010). Grounded Theory Method in HCI and CSCW, Cambridge, IBM Center for Social Software, 28(2), 1–46.

Ogilvie, J.W. (1992). Adult scoliosis: evaluation and nonsurgical treatment, Instructional course lectures, 41, 251–255.

Robin, G.C. et al. (1982). Scoliosis in the elderly: a follow-up study, Spine, 7(4), 355–359.

Saldaña, J. (2009). The coding manual for qualitative researchers, The coding manual for qualitative researchers, Thousand Oaks, CA, Sage Publications Ltd.

Sani, M.N.A. et al. (2020). The appropriation of product design as solution to minimise risk of exertional heat illness among Marathon runners, International Journal of Human Movement and Sports Sciences, 8(6), 63–67.

Schütte, S. (2005). Engineering emotional values in product design: Kansei engineering in development, Institutionen för konstruktions-och produktionsteknik.

Seeger, B.R. & Sutherland, A.D. (1981). Modular seating for paralytic scoliosis: Design and initial experience, Prosthetics and Orthotics International, 5(3), 121–128.

Sponseller, P.D. et al. (1987). Results of surgical treatment of adults with idiopathic scoliosis, The journal of bone and joint surgery, 69(5), 667–675.

Utkan, F., Fredericks, T.K. & Butt, S.E. (2011). The effect of scoliosis curvature on lumbar support for task seating., Proceedings of the 2011 Industrial Engineering Research Conference.

Velis, K.P., Healey, J.H. & Schneider, R. (1988). Osteoporosis in unstable adult scoliosis, Clinical orthopaedics and related research, 237, 132–141.

Winter, R.B. & Lonstein, J.E. (1983). Adult scoliosis, Instructional course lectures, 32, 170–191.

Zhuopeng, L., & Mohamed, M. J. Kamil (2023). Incorporating The Influence of Regional Culture in Tableware Design: The Case Study of Chaoshan Area, Wacana Seni Journal of Arts Discourse, 22, 17–33.

AUTHOR BIOGRAPHIES

Muhammad Jameel Mohamed Kamil is an experience academician working as a Senior Lecturer specializing in the area of Industrial Design at the Faculty of Applied and Creative Arts (FACA), Universiti Malaysia Sarawak. He was formerly an industrial designer at Artmatrix Technologies SDN BHD and a Senior Lecturer at the School of The Arts, Universiti Sains Malaysia, where he focused on product design. He received his Ph. D degree in Design Science and M.A degree in Art & Design from Universiti Teknologi MARA (UiTM). He also holds B.F.A (Hons) degree in Product Design from Universiti Sains Malaysia (USM). His specific areas of interest, publication, and supervision are in de-sign sciences and looking at medical product design. His practice crosses disciplines and media, engaging 3D design technology, user interaction, product design development, and furniture as stages of merging. His research contributions include copyrights, industrial design registrations, and articles publications in international journals as well as at international conferences.

Nazratul Nadiah Samsuddin is an experienced designer who works for a renowned Selangor's firm. She received a B.F.A. (Hons) in Product Design from the School of Arts at Universiti Sains Malaysia (USM). Her areas of competence include design sketching, product design, 3D modelling based on human experience, and graphic design.

Mohd Najib Abdullah Sani is an experienced academic. Over the past 20 years teaching in the higher learning institutions, he has demonstrated a strong commitment to teaching, research, and service in the field of art and design. He is currently serving as the Deputy Director of the University Industry Centre (UnIC) at Universiti Malaysia Sarawak.

Amir Hassan bin Mohd Shah is an experienced academic works as a Lecturer in the Faculty of Applied and Creative Arts (FACA), Universiti Malaysia Sarawak, with a focus on industrial design. He used to work as a freelance industrial designer for both domestic and foreign automakers. He graduated from the Institute of Design and Innovation (INDI) with an M.A. in Art & Design. Additionally, he graduated from Universiti Malaysia Sarawak with a B.F.A (Hons) in Design Technology. His areas of expertise include product and automobile design, 3D modelling, and design sketching.

DOI: 10.6977/IJoSI.202406_8(2).0005
R. Ch, M. Sridevi, et al../Int. J. Systematic Innovation, 8(2), 58-69 (2024)

Enhancing digital security using Signa-Deep for online signature verification and identity authentication

Ravikumar Ch[1], Mulagundla Sridevi[2], M Ramchander[3], Vankudoth Ramesh[4], Vadapally Praveen Kumar[5]
[1]Assistant Professor, Department of Artificial Intelligence &Data Science,
Chaitanya Bharathi Institute of Technology, Hyderabad, India-500075.
[2]Associate Professor, Department of Computer Science and Engineering,
CVR College of Engineering, Hyderabad, India-501510
[3]Assistant Professor, Department of Master of Computer Applications,
Chaitanya Bharathi Institute of Technology, Hyderabad, India-500075.
[45]Assistant Professor, Department of Emerging Technologies.
CVR College of Engineering, Hyderabad-500039.
* Corresponding author E-mail: chrk5814@gmail.com
(Received 23 October 2023; Final version received 61 January 2024; Accepted 16 April 2024)

Abstract

In the contemporary digital realm, the utilization of online services has surged, facilitated by the seamless integration of deep learning technology, which is paramount in applications demanding precision and efficiency. A pivotal use case in this context is online handwritten signature verification, where the need for exceptional accuracy is indisputable. This paper introduces 'Signa-Deep,' an innovative approach designed to address the challenge of online signature verification and the determination of an individual's authorization status. The study explores a range of methodologies, including Convolutional Neural Networks (CNN), Long Short-Term Memory (LSTM), GoogleNet, and MobileNet, to discern the authenticity of signatures and affirm the identity of the signatory. The results of our proposed method are promising, showcasing its potential to significantly enhance the security of digital transactions and identity verification processes. In summary, 'Signa-Deep' harnesses deep learning technology to bolster the accuracy and reliability of online signature verification, thereby contributing to the overall robustness of digital interactions and identity validation processes.

Keywords: Deep Learning, Online Signature Verification, Authorization Status, Identity Authentication, Digital Transactions Security

1. Introduction

As a biometric feature used for user identification, the human signature makes signature verification a persistent area of study. Online and offline signatures are the two main categories into which signatures fall. Signatures are widely used as a form of authentication. Online signatures, also called dynamic signatures, are digital signatures that are recorded in databases after being digitally taken with electronic equipment. Dynamic characteristics include things like the number and sequence of strokes, the speed at which the signature is made, and the pressure distribution at different points, which make the signature difficult to copy and distinctly unique. After the signature is preprocessed, certain attributes are taken out. User enrollment in an online signature verification system begins with the submission of reference signatures or samples of signatures. Following that, if a user signs a document (called a test signature) to prove who they are, the test signature is compared to the reference signatures linked to that person. The user's request is rejected if the discrepancy is more than a set quantity. Offline signatures, also known as static signatures, originate as ink-on-paper signatures, which are subsequently preserved by scanning to create a digital copy. In practice, it is essential to verify the authenticity of both online and offline signatures. Nevertheless, verifying offline signatures poses a greater challenge since, unlike their online counterparts, they lack dynamic data (N. Abbas et 2012 & Neha et. 2022).

Numerous sectors, including banks, official documents, and receipts, rely on online signatures to enhance security and establish the identity of the respective individuals. Although each person possesses a unique signature, the challenge lies in consistently reproducing the same signature. The primary objective of signature verification is to reduce intra-individual variations. Online signature verification constitutes the process of confirming the author's identity through a signature verification system (O.Shapran & M. C. Fairhurst 2009). This system can serve as a security measure, facilitating verification for purposes such as access control and password replacement. Utilizing signature verification enables organizations to validate the legitimacy of customer signatures (Y. Ren et 2020.)

Signature verification is a method employed by banks, intelligence agencies, and prestigious organizations to authenticate an individual's identity. This technique is frequently utilized for comparing signatures within bank offices and other branch capture processes. Online signature verification utilizes signatures recorded using pressure-sensitive tablets, which capture not only the signature's shape but also its dynamic properties (C. Y. Low et 2007).

During the verification process, various distance measures are produced by comparing the test signature to every signature in the reference set. Consequently, a methodology for combining these distance values into a single metric that represents the difference between the test signature and the reference set must be implemented. After that, a predetermined threshold is compared to this statistic to make a decision. One can determine the single dissimilarity value by taking the average, maximum, or minimum of all the distance measurements. A verification system usually selects one of these measures and ignores the others.

Determining if a handwritten signature is real or fake is part of the online handwritten signature verification process. It is possible to fake signatures, and these fakes fall into five different categories: self-forgery, random, skilful, basic, and fluent.

a) **Random forgery:** Generated without any prior knowledge of the signature, its shape, or the signer's identity.
b) **Simple forgery:** Produced with only knowledge of the signer's name, lacking any reference to the signer's signature style.
c) **Skilled forgery:** Crafted by observing an authentic signature sample and endeavoring to replicate it as faithfully as possible. This type of forgery involves having access to a sample of the signature to be duplicated. The quality of a skilled forgery relies on factors such as the forger's practice, their skill level, and their meticulous attention to detail in mimicking the original signature. A skilled forgery closely resembles a genuine signature.
d) **Fluent forgery:** The forger aims to imitate the motion of the signature, often resulting in rapid scribbling that overlooks design elements such as the shape of letters.
e) **Self-forgery:** A specific type of forgery in which an individual forges their signature intending to deny it at a later stage."

The complexity of the signature verification task increases notably when transitioning from simple to skilled forgery. Consequently, crafting an effective signature verification system poses a significant and critical challenge (Chang et.2023).

The vital and complex field of signature verification, which is essential for user identification using the biometric characteristic of a human signature, is the subject of this study. Differentiating between offline and online signatures, the study emphasizes how online signatures are more dynamic and difficult to duplicate. Reference signatures are submitted as part of the registration procedure, and these signatures serve as the foundation for identity verification utilizing comparison with test signatures that are later submitted. Because they are not dynamic, offline signatures which started as ink on paper and were subsequently digitized present a unique set of challenges. Despite these difficulties, online and offline signatures are essential for improving security and verifying personal identity in a variety of industries, such as banking, intelligence services, and elite institutions. The main objective of the work is to tackle the crucial problem of intra-individual differences in signatures, which is necessary for the creation of efficient signature verification systems with security, access control, and password replacement applications in mind.

Additionally, the study explores how difficult it is to verify the veracity of handwritten signatures, classifying fakes into various categories. Verifying a signature becomes more difficult when moving from simple to professional forgeries. This investigation clarifies the constantly changing field of biometric authentication and offers insightful information about the enduring difficulties encountered by industries that depend on signature validation for identity authentication. The study's importance originates from its thorough examination of signature verification, which provides a sophisticated grasp of the complexities involved and advances the development of efficient identification validation systems.

1.2 Major Contributions of the Study

a) **Static vs. Dynamic Signatures:** The study highlights the difficulties in validating static signatures in the absence of dynamic data and elucidates the distinctions between dynamic (online) and static (offline) signatures.
b) **Applications and Difficulties by Sector:** It highlights how commonplace online signatures are in industries like banking and documents, but it also notes how hard it is to reliably replicate original signatures, particularly when offline verification is involved.
c) **Minimizing Intra-Individual Variation:** The study acknowledges that the primary objective of signature verification is to minimize variances within a single signature. This knowledge is essential for creating secure, access-control, and password-replacement systems that work.
d) **Forgery Categories and Complexity:** The study clearly illustrates the complexity involved, especially when dealing with sophisticated forgeries, by classifying signature forgeries into five categories.

Crafting an effective system to address the complexity of skilled forgeries entails recognizing the substantial challenge inherent in developing signature verification systems capable of discerning sophisticated attempts to replicate genuine signatures. This understanding serves as the cornerstone for the advancement of future biometric authentication systems.

The subsequent sections of this article are structured as outlined below: In Section II, prior research in signature verification through deep learning is outlined. Section III provides comprehensive insights into our proposed algorithms: CNN, LSTM, GoogleNet, and MobileNet. Section IV presents a comparative analysis of the algorithms, focusing on accuracy scores. Finally, in Section V, we draw our ultimate conclusions.

2. Related Work

(Ata Larijani et.al) the authors address the critical issue of safeguarding data collected by smart meters to protect consumer privacy. Emphasizing the potential threats posed by data disclosure, the paper focuses on developing a platform for dynamic pricing to enhance the efficiency of electricity facilities. Unlike previous research, this study prioritizes user authentication, aiming to provide an efficient and comprehensive privacy-preserving solution for smart electricity networks. The proposed method, involving mutual authentication and key agreement between entities, significantly reduces computational complexity and communication overhead while maintaining resistance to various attacks.

(Ata Larijani et.al 2024) present an in-depth exploration of an enhanced intrusion detection method for multiclass classification. The paper introduces a novel approach employing the modified teaching–learning-based optimization (MTLBO) and modified JAYA (MJAYA) algorithms in conjunction with a support vector machine (SVM). MTLBO aids in feature subset selection, optimizing feature subsets for improved intrusion detection accuracy. The study demonstrates the effectiveness of the proposed MTLBO-MJAYA-SVM algorithm, surpassing the performance of original TLBO and JAYA algorithms on a well-established intrusion detection dataset. This research contributes to advancing optimization techniques in the domain of intrusion detection systems.

(R. Choupanzadeh et al 2023) focus centers on the development of a deep neural network (DNN) modeling methodology to predict radiated emissions from a shielding enclosure. The authors investigate the impact of aperture attributes, such as shape, size, pitch, and quantity, on the radar cross section (RCS) of a 3D enclosure resembling a desktop PC. The study employs the modified equivalent current approximation

(MECA) method to generate training data for machine learning, comparing its validity against analytical methods and a commercial field-solver. Through an exploration of various DNN models, the authors identify optimal configurations based on accuracy, computation time, and memory usage. The results demonstrate strong agreement between MECA and DNN predictions for previously unseen cases, highlighting the potential of this approach for efficient electromagnetic compatibility (EMC) assessment in electronic devices.

(Raveen Wijewickrama et.al 2023) address emerging security concerns associated with the integration of sensors in headphones. Traditional audio playback devices, now equipped with high-definition microphones and accelerometers, may inadvertently pose eavesdropping vulnerabilities. This work introduces OverHear, a framework leveraging acoustic and accelerometer data to infer keystrokes, emphasizing clustering by hand position and individual keystroke distinction through Mel Frequency Cepstral Coefficients (MFCC) analysis. Machine learning models and dictionary-based word prediction refine the results. Experimental tests demonstrate top-tier accuracy, around 80% for mechanical and 60% for membrane keyboards, with over 70% accuracy in top-100-word predictions across all keyboard types. The study highlights both the effectiveness and limitations of the proposed approach in real-world scenarios.

Kamran et.al addresses the critical role of short-term load forecasts (STLF) in power system operation and planning. Their proposed hybrid method combines artificial neural network (ANN) and artificial bee colony (ABC) algorithms, utilizing ABC to optimize ANN's learning procedure. Incorporating new load modeling based on historical and weather data, the method considers bad data elimination and calendar effects, enhancing STLF accuracy. Verified by forecasting Bushehr province demand, the results demonstrate significant improvements, underscoring the efficacy of the proposed hybrid approach in STLF precision enhancement.

(J. Vajpai et al. 2013) introduce an innovative approach to dynamic signature verification for safeguarding classified online information. Given the accessibility of sensitive data on e-commerce websites, the authors advocate a method that combines a password or PIN with a digital signature to ensure user authentication.(H. Shekar et al. 2011) introduce a robust online signature verification model that operates in stages. During the initial stage, signature preprocessing is carried out, followed by the construction of an Eigen signature from the preprocessed signature data. This model has been applied to offline Kannada signatures.

According to (D. Falahati et al. 2011), signature verification holds significant importance in financial management. The authors have introduced an approach that utilizes Discrete Time Warping for signature matching. As per the research conducted by (M. Fayyaz et al. 2015), feature extraction and feature selection are pivotal elements in the field of signature verification. The author introduces a novel approach centred on feature learning through a sparse autoencoder. These learned features serve as representations for user signatures. The study leverages the SVC2004 signature database for verification, which includes both authentic and forged signatures, enabling robust training and testing to enhance the model's accuracy. (R. C. Sonawane et al. 2012), delineated the diverse attributes of a dynamic signature captured using a digital tablet and a dedicated pen linked to the computer's USB port. The authors examined both spatial and temporal characteristics to authenticate legitimate signatures.

3. Methodology
3.1 Data collection and preprocessing

We present an extended overview of the methodological framework employed in our study.

a) **Dataset Description:** The real-time dataset used in our experiment encompasses a total of 1,000 signatures collected from 500 distinct participants. This dataset is evenly divided, consisting of 500 real signatures and 500 fake signatures. To ensure a robust evaluation, we implemented an 80-20 data split strategy. This involved allocating 80% of the dataset for the training phase, allowing the model to learn from the majority of the data, while the remaining 20% was earmarked for rigorous testing, ensuring a comprehensive assessment of the model's performance.
b) **Data Preprocessing Significance:** Recognizing the paramount importance of data preparation in guaranteeing the dependability and

efficiency of deep learning models, our methodology places a strong emphasis on this critical stage. The primary goal of data preprocessing is to transform raw, unprocessed data into a format conducive to the utilization of deep learning models. Particular attention is given to noise reduction, a key component in preparing signature images. During the data collection phase, inadvertent noise artifacts may find their way into signature scans, and meticulous treatment of these artifacts is undertaken to enhance the accuracy and resilience of the model.

c) **Deep Learning Algorithm and Feature Extraction:** Following data preprocessing, our study employs a deep learning algorithm to extract intricate features from the signatures. This process plays a pivotal role in assessing the authenticity of signatures, focusing on the model's ability to distinguish between genuine and forged signatures. This task is of paramount importance in the domain of signature verification, contributing significantly to the overall success of our approach.

d) **Experimental Process:** Illustrated in Figure 1, the experimental process provides a visual representation of the successful application of our deep learning model. This showcases the model's capability to achieve the crucial distinction between genuine and forged signatures. The demonstrated success of our approach holds promising implications for the enhancement of digital security and identity verification processes.

In conclusion, the extended methodology not only addresses the reviewer's valuable comments but also provides a more detailed and comprehensive insight into the robustness of our experimental framework. We believe that these refinements contribute significantly to the transparency, reproducibility, and overall quality of our study

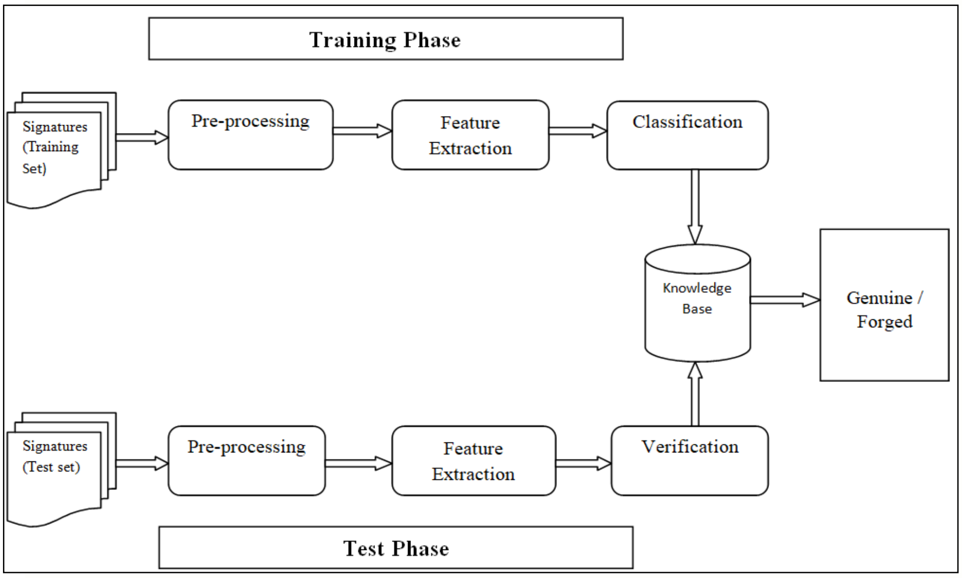


Figure 1. Architecture of Signature verification

3.2 Models

We employed four distinct models on the signature dataset for comparative analysis. Subsequently, the best-performing model was employed for real-time signature verification. The models employed include CNN, LSTM, GoogleNet, and MobileNet.

3.2.1 CNN

A Convolutional Neural Network (CNN) is a deep learning algorithm employed with image datasets for tasks such as classification, verification, recognition, or detection (K. Anatska et al. 2022 & B.H. Shekar et al. 2022).

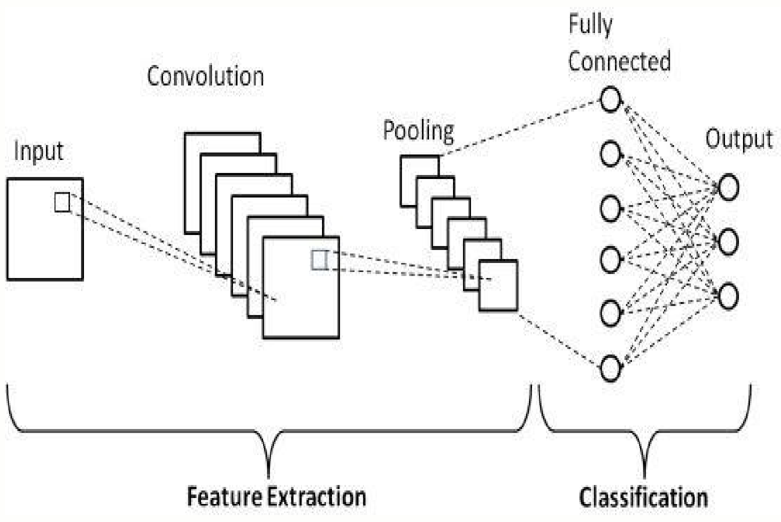


Figure 2. CNN architecture

The CNN architecture comprises several key layers (R. C. Suganthe et al. 2022) as shown in Figure 2:

a) **Convolutional Layer:** This layer operates on the input image to extract meaningful features.
b) **Pooling Layer:** Responsible for downsampling the image, common pooling methods include max pooling, min pooling, and average pooling (M. Mutlu et al. 2018).
c) **Fully Connected Layer:** The final layer of the CNN is primarily utilized for classification tasks.

Additionally, activation functions like ReLU are applied to introduce non-linearity into the network, enhancing its capacity to capture complex patterns.

3.2.2 LSTM

LSTM, an acronym for Long Short-Term Memory, belongs to the category of recurrent neural networks (RNNs). LSTM networks have been designed to overcome the limitations inherent in traditional RNNs (J. Vajpai et.2013). They prove highly effective in addressing tasks involving sequential data, such as speech recognition, analysis of time series data, and more. The LSTM model is depicted in Figure.

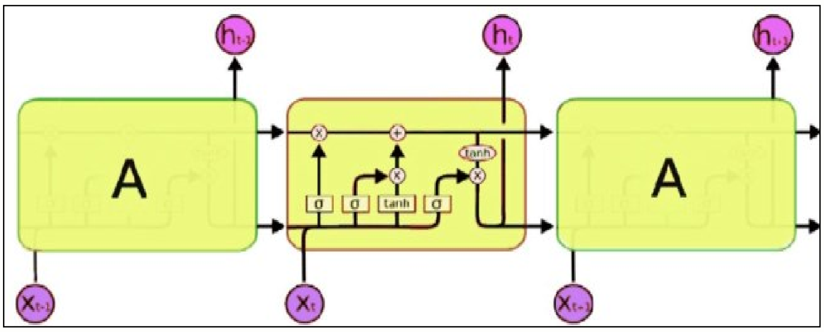


Figure 3. LSTM architecture

a) The principal components within LSTM architecture encompass:

1. Memory Cells: These specialized units serve the critical role of storing information across extended sequences, making them indispensable when dealing with long-term dependencies.

2. Gates: LSTM incorporates distinct gates, including the input gate, forget gate, and output gate. These gate mechanisms control the flow of information in and out of the memory cell, enabling the selective retention, removal, or access to information.

- Input Gate: Regulates the input information that gets stored within the memory cell.

- Forget Gate: Determines the relevance of information and facilitates its removal from the memory cell.

- Output Gate: Dictates which information should be read from the memory cell to generate the final output.

3. Cell State: LSTM networks maintain a cell state, effectively functioning as a conduit for information transfer across various time steps, adhering to the specific requirements of the task at hand.

3.2.3 Google Net

GoogleNet also referred to as Inception-v1, was developed by Google's research team and is primarily employed for tasks related to image classification. The inception module of GoogleNet is shown in Fig4.

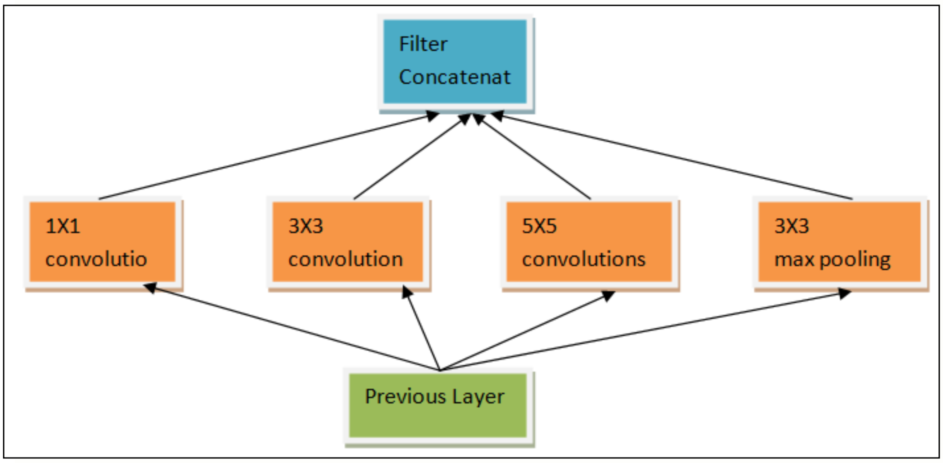


Figure 4. Inception module of GoogleNet

b) Key elements within the GoogleNet architecture include:

1. **Inception Module:** The hallmark of GoogleNet, the inception module, incorporates multiple filters of varying kernel sizes within the same layer. This design facilitates the simultaneous extraction of features at diverse scales, leading to enhanced model performance. The inception module features parallel paths and pooling layers for dimensionality reduction.
2. **Global Average Pooling:** GoogleNet adopts global average pooling as an approach to reduce the spatial dimensions of feature maps, aiding in the generation of predictions. This technique helps mitigate the risk of overfitting.
3. **Auxiliary Classifiers:** In GoogleNet, auxiliary classifiers are strategically placed at intermediate layers of the network. These auxiliary classifiers provide additional supervision during the training process, serving as a countermeasure against the vanishing gradient problem.

GoogleNet stands as a significant achievement in deep learning (B. H. Shekar et.2011), showcasing the potential for deep neural networks to achieve both high accuracy and computational efficiency. Its architectural innovations have influenced subsequent models and found applications in various computer vision tasks, including image classification and object detection.

3.2.4 MobileNet

"Developed by Google researchers, MobileNet is specifically tailored for mobile and embedded devices, demonstrating remarkable efficiency in image classification and object detection tasks, all the while conserving memory and computational resources (D.Falahati et al. 2011).

a) MobileNet encompasses the following components as depicted in Figure.5:

1. **Depth-wise Separable Convolution:** MobileNet employs depth-wise separable convolutions, which segregate spatial and depth-wise convolutions. This approach substantially diminishes both the parameter count and computational load.
2. **Point-wise convolution** often referred to as 1x1 Convolution, utilizes a compact kernel size to conduct convolution on the input data. This operation spans all channels and consolidates information from various channels at each spatial position. It plays a crucial role in adjusting the model's width, influencing its computational intensity. Typically, it is employed in conjunction with depth-wise convolution to enhance the efficacy of feature capture.
3. **Width Multiplier (Alpha):** Among the hyperparameters available, the width multiplier denoted as 'alpha' allows precise control over the number of channels in each layer. This strategic adjustment enhances model compactness.
4. **Resolution Multiplier (Rho):** Another valuable hyperparameter, the resolution multiplier ('rho'), empowers users to downscale the input image resolution. This, in turn, leads to reductions in both memory consumption and computational demands.

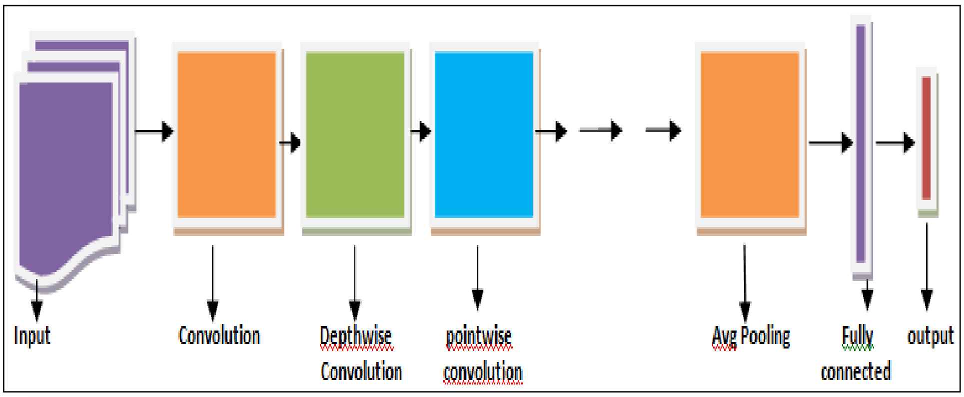


Figure 5. Architecture of MobileNet

4. Results

In this paper, we have also developed a dashboard capable of receiving signature images as input and providing feedback on their authenticity as illustrated in **Figure 6**. We employed four distinct algorithms to assess their performance in distinguishing between genuine and forged signatures. The evaluation was conducted on a consistent dataset, allocating 80% for training and 20% for testing.

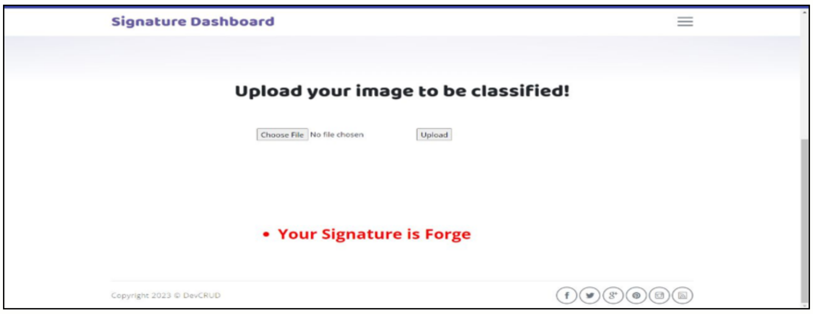


Figure 6. Dashboard showing signature is forged

Table 1. Results summary table

S.No	Algorithm	Accuracy (%)
1	CNN	98
2	MobileNet	93
3	LSTM	50
4	GoogleNet	50

The findings of our study are now presented in a clear and organized manner, including accuracy scores and relevant performance metrics. Table 1 serves as a results summary, outlining the accuracy percentages achieved by four distinct algorithms in distinguishing between genuine and forged signatures during both the training and testing phases.

During the training phase, CNN emerged as the standout performer, achieving an impressive accuracy rate of 98%. This exceptional performance underscores the robustness of the Convolutional Neural Network in the context of signature verification. MobileNet also exhibited noteworthy accuracy at 93%, showcasing its potential for reliable results in both phases. In contrast, LSTM and GoogleNet both displayed similar accuracy levels of 50% during the training phase, suggesting that they might require further refinement to match the performance of CNN and MobileNet.

The consistency of these results between the training and testing phases is remarkable. CNN and MobileNet maintained their high accuracy levels, reinforcing their reliability in both phases. Meanwhile, LSTM and GoogleNet, while not as accurate as CNN and MobileNet, demonstrated stable performance across the different data subsets. These findings highlight CNN's superiority in signature verification and its potential to enhance the security of digital transactions and identity verification processes.

Figure 8 has been incorporated to enhance the understanding and comparison of the results. This accuracy comparison chart visually illustrates the performance of CNN, LSTM, GoogleNet, and MobileNet algorithms. The graphical representation provides a concise overview of the relative accuracies of these models.

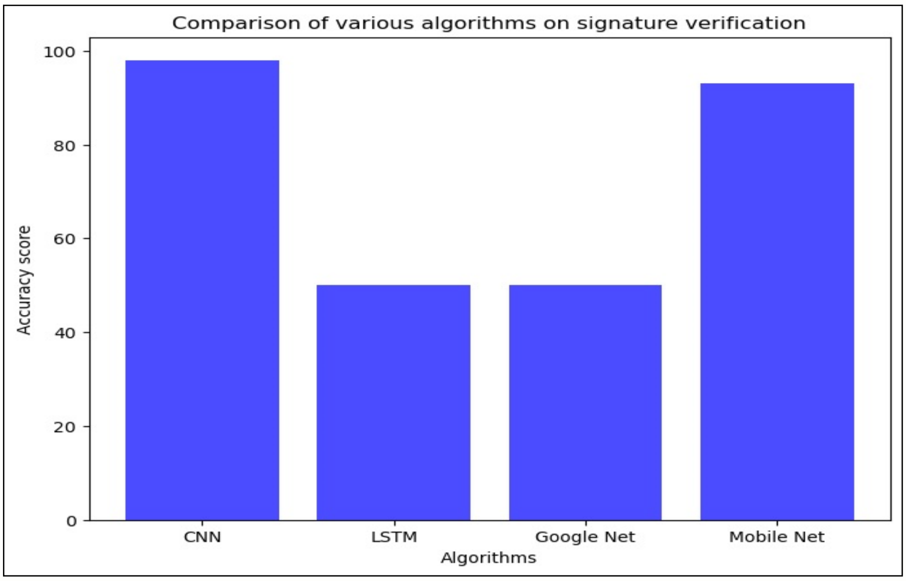


Figure 8. An accuracy comparison chart of CNN, LSTM, GoogleNet, and MobileNet algorithms

5. Conclusion and future scope

This work explores the field of signature verification for behavioral authentication, which is a commonly used technique for user authentication. Utilizing a real-time dataset including 500 unique users and equal distribution of 500 authentic and 500 fraudulent signatures, we conducted a detailed examination of four distinct algorithms – CNN, LSTM, GoogleNet, and MobileNet. With an astounding accuracy of 98%, CNN stood out as a particularly strong performer, demonstrating its resilience in signature verification. Additionally, MobileNet showed dependability with a respectable 93% accuracy rate. By comparison, the accuracy rates of LSTM and GoogleNet were 50%, suggesting areas that could benefit from further development. The study also presents an easy-to-use dashboard that is intended to facilitate effective signature verification, offering a useful instrument for identity authentication procedures.

Future scope: To improve identity authentication systems, this research will broaden the incorporation of biometric elements like fingerprint or face recognition. The goal of additional research and architecture optimization for GoogleNet and LSTM is to improve overall performance and accuracy. The emergence of real-time online signature verification capabilities creates opportunities for instantaneous authentication in digital transactions, necessitating additional research into these models' computing efficiency. Future research endeavors will further enhance and modify signature verification methods in response to technological advancements, guaranteeing improved precision, safety, and usability in the ever-changing identity authentication field.

References

Larijani, A., & Dehghani, F. (2024). Computationally Efficient Method for Increasing Confidentiality in Smart Electricity Networks. Electronics, vol. 13, no. 1, 2024, p. 170. https://doi.org/10.3390/electronics13010170.

Shekar, B. H.& Bharathi, R. K. (2011). Eigen-signature: A Robust and an Efficient Offline Signature Verification Algorithm. 2011 International Conference on Recent Trends in Information Technology (ICRTIT), Chennai, India, 2011, pp. 134-138. doi: 10.1109/ICRTIT.2011.5972461.

Shekar, B. H., Abraham, W. & Pilar, B. (2022) Offline Signature Verification Using CNN and SVM Classifier. 2022 IEEE 7th International Conference on Recent Advances and Innovations in Engineering (ICRAIE), Mangalore, India, 2022, pp. 304-307. doi: 10.1109/ICRAIE56454.2022.10054336.

Low, C. Y., Teoh, A. B. J. & Tee, C. (2007) A Preliminary Study on Biometric Watermarking for Offline Handwritten Signature. 2007 IEEE International Conference on Telecommunications and Malaysia International Conference on Communications, Penang, Malaysia, 2007, pp. 691-696. doi: 10.1109/ICTMICC.2007.4448568.

Chang, S. J., & Wu, T. R. (2023). Development of a Signature Verification Model Based on a Small Number of Samples. Signal, Image and Video Processing, 2023, pp. 1-10.

Falahati, D., Helfrush, M. , Danyali, H. & Rashidpour, M. (2011). Static Signature Verification for Farsi and Arabic Signatures Using Dynamic Time Warping. 2011 19th Iranian Conference on Electrical Engineering, Tehran, Iran, 2011, pp. 1-1.

Vajpai, J., Arun, JB, & Vajpai, I. (2013). Dynamic Signature Verification for Secure Retrieval of Classified Information. 2013 Fourth National Conference on Computer Vision, Pattern Recognition, Image Processing and Graphics (NCVPRIPG), Jodhpur, India, 2013, pp. 1-4. doi: 10.1109/NCVPRIPG.2013.6776170.

Anatska, K., & Shekaramiz, M. (2022). Offline Signature Verification: A Study on Total Variation versus CNN. 2022 Intermountain Engineering, Technology and Computing (IETC), Orem, UT, USA, 2022, pp. 1-6. doi: 10.1109/IETC54973.2022.9796924.

Larijani, A., & Dehghani, F. (2024). An Efficient Optimization Approach for Designing Machine Models Based on Combined Algorithm. FinTech, vol. 3, no. 1, 2024, pp. 40-54. https://doi.org/10.3390/fintech3010003.

Fayyaz, M., Saffar, M. H., Sabokrou M., Hoseini, M. & Fathy, M. (2015). Online Signature Verification Based on Feature Representation. 2015 The International Symposium on Artificial Intelligence and Signal Processing (AISP), Mashhad, Iran, 2015, pp. 211-216. doi: 10.1109/AISP.2015.7123528.

Yapici, Mutlu, Tekerek, M. A.& Topaloglu, N. (2018). Convolutional Neural Network Based Offline Signature Verification Application. 2018 International Congress on Big Data, Deep Learning and Fighting Cyber Terrorism (IBIGDELFT), Ankara, Turkey, 2018, pp. 30-34. doi: 10.1109/IBIGDELFT.2018.8625290.

Abbas, N., & Chibani, Y. (2012). SVM-DSmT Combination for Off-Line Signature Verification. 2012 International Conference on Computer, Information and Telecommunication Systems (CITS), Amman, Jordan, 2012, pp. 1-5. doi: 10.1109/CITS.2012.6220365.

Sharma, Neha, Gupta, Sheifali, Mehta, Puneet , Cheng, Xiaochun, Shankar, Achyut, Singh, Prabhishek & Nayak, Soumya Ranjan. (2022). Offline Signature Verification Using a Deep Neural Network with Application to Computer Vision. Journal of Electronic Imaging, vol. 31, no. 4, 2022, p. 041210. doi: 10.1117/1.JEI.31.4.041210.

Shapran, O., & Fairhurst, M. C. (2009). Enhancing Signature Verification Using Alternative Handwriting Semantics. 3rd International Conference on Imaging for Crime Detection and Prevention (ICDP 2009), London, 2009, pp. 1-6. doi: 10.1049/ic.2009.0242.

Sonawane, R. C., & Patil, M. E. (2012). An Effective Stroke Feature Selection Method for Online Signature Verification. 2012 Third International Conference on Computing, Communication and Networking Technologies (ICCCNT'12), Coimbatore, India, 2012, pp. 1-6. doi: 10.1109/ICCCNT.2012.6395926.

Suganthe, R. C., Geetha, M., Sreekanth, G. R., Manjunath, R., Krishna, S. M. & Balaji, P. M. (2022). Performance Evaluation of Convolutional Neural Network Based Models on Signature Verification System. 2022 International Conference on Computer Communication and Informatics (ICCCI), Coimbatore, India, 2022, pp. 1-6. doi: 10.1109/ICCCI54379.2022.9741030.

Choupanzadeh, R., & Zadehgol, A. (2023). A Deep Neural Network Modeling Methodology for Efficient EMC Assessment of Shielding Enclosures Using MECA-Generated RCS Training Data. IEEE Transactions on Electromagnetic Compatibility, vol. 65, no. 6, 2023, pp. 1782-1792. doi: 10.1109/TEMC.2023.3316916.

Wijewickrama, R., Abbasihafshejani, M., Maiti, A. & Jadliwala, M.. (2023). OverHear: Headphone-Based Multi-Sensor Keystroke Inference. arXiv preprint arXiv:2311.02288, 2023.

Ren, Y., Wang, C. Chen, Y. , Chuah, M. C. & Yang, J. (2020). Signature Verification Using Critical Segments for Securing Mobile Transactions. IEEE Transactions on Mobile Computing, vol. 19, no. 3, 2020, pp. 724-739. doi: 10.1109/TMC.2019.2897657.

DOI: 10.6977/IJoSI.202406_8(2).0005
R. Ch, M. Sridevi, et al../Int. J. Systematic Innovation, 8(2), 58-69 (2024)

AUTHOR BIOGRAPHIES

Ravikumar Ch is an accomplished professional in the field of Computer Science & Engineering. He obtained his B.Tech. Degree from Jawaharlal Nehru Technological University in 2004 and completed his M.Tech in 2011. Currently, he is pursuing a PhD in Computer Science & Engineering at Lovely Professional University. He holds the position of Assistant Professor at Chaitanya Bharathi Institute of Technology (AI & DS), which is affiliated with Osmania University. In his role, Ravikumar imparts knowledge and mentors students in the field of computer science. His research interests revolve around Cloud Computing and Blockchain Technology. For any inquiries or further communication, he can be contacted at chrk5814@gmail.com.

Mulagundla Sridevi received Ph.D. degree in Computer Science and Engineering from Jawaharlal Nehru Technological University Hyderabad (JNTUH), Hyderabad in 2020. She has 23 years of teaching and research experience. Currently, working as an Associate Professor at the Department of CSE, CVR College of Engineering, Ibrahimpatnam, RR District, and Telangana, India. She is a Life Member for ISTE and a Member of CSI. Her research areas of interest are Security in databases and Web Applications, Machine Learning, data science, Data mining, and Artificial Intelligence. She has published more than 30 research papers in National and International Journals, SCI and published a book chapter in Springer, and attended several National and International conferences. She can be contact at sreetech99@gmail.com.

Dr. M. Ramchander is an accomplished professional in the field of Computer Science and engineering. He obtained M.Tech (CSE) from Osmania University in 2005 and completed his Ph.D.(CSE) from Osmania University in 2023. He holds the position of an Assistant Professor at Chaitanya Bharathi Institute of Technology (Dept. of MCA), which is affiliated with Osmania University. In his role, Dr. M. Ramchander imparts knowledge and mentors students in the field of computer science. His research interests revolve around Databases, Data Mining, Big Data and Machine Learning. For any inquiries or further communication, he can be contacted at go2ramchander@gmail.com.

Vakudoth Ramesh is an accomplished professional in the field of Computer Science & Engineering. He obtained his B.Tech. Degree from Jawaharlal Nehru Technological University Hyderabad in 2010 and completed his M.Tech in 2012. Currently, he is pursuing a Ph.D. in Computer Science & Engineering at Jawaharlal Nehru Technological University Anantapur. He holds the position of Assistant Professor at CVR College of Engineering (DS), which is affiliated with Jawaharlal Nehru Technological University Hyderabad. In his role, Vankudoth Ramesh imparts knowledge and mentors students in the field of computer science. His research interests revolve around Blockchain Technology and Network Security. For any inquiries or further communication, he can be contacted at v.ramesh406@gmail.com.

Vadapally Praveen Kumar is an accomplished professional in the field of Computer Science & Engineering. He obtained his M.Tech. Degree from Jawaharlal Nehru Technological University in 2014 and currently, he is pursuing a PhD in Computer Science & Engineering at SR University, Warangal. He holds the position of Assistant Professor at CVR College of Engineering in the department of Data Science, which is affiliated with JNTUH. In his role, Praveen Kumar imparts knowledge and mentors students in the field of computer science. His research interests revolve around Internet of things and Cloud Computing. For any inquiries or further communication, he can be contacted at micro091983@gmail.com

DOI: 10.6977/IJoSI.202406_8(2).0006
P. Abhijeet, S. Sanjeev, et al./Int. J. Systematic Innovation, 8(2), 70-86 (2024)

Zero-waste toilet a sensor-operated urine diverting toilet for sustainable sanitation and fertilizer production

Patil Abhijeet[1]*, Sangami Sanjeev[2], Chandak Piyush.G[3]

[1]*Research scholar, Visvesvaraya Technological University, Belagavi, Karnataka, India. 590018, Belagavi, Karnataka, India.

[2]Research supervisor, Visvesvaraya Technological University, Belagavi, Karnataka, India 590018, Belagavi, Karnataka, India.

[3]Research cosupervisor, Visvesvaraya Technological University, Belagavi, Karnataka, India 590018, Belagavi, Karnataka, India.

*Corresponding author mail: patilabhijeet275@gmail.com

(Received 13 December 2023; Final version received 23 January 2024; Accepted 8 February 2024)

Abstract

This research introduces an innovative zero-waste toilet, a sensor-operated urine-diverting system designed to overcome limitations in current sanitation methods. The toilet directly converts human feces into organic fertilizer while segregating urine from solid waste. Its walls are constructed using repurposed plastic PET bottles filled with local soil, enhancing strength and durability through steel wire interconnection and cement plaster reinforcement. Touchless sensors facilitate automatic flushing upon user entry and after a predetermined duration, with a gesture sensor for post-use cleaning. A front-mounted urine basin ensures proper waste separation. Feces are directed to a specialized tank via a trap system, while urine is directed to the sewer line. The tank features two meshes for effective filtration. Solar energy and sensors power the process, enabling atomization for efficient fertilizer production, followed by composting in a blending tank. The zero-waste toilet offers a key advantage: fertilizer production without manual waste handling, aligning with scavenger act regulations. It minimizes waste generation, conserves water, and enhances sanitation. Repurposed plastic bottles reduce plastic pollution, and the system is comfortable, durable, and resource-efficient. Challenges include specialized expertise, initial costs, and user adaptation to automated systems. Further research is needed to optimize fertilizer production from waste compost. Nonetheless, the zero-waste toilet holds promise for sustainable sanitation, improved hygiene, and resource conservation.

*Keywords: zero-waste toilet, urine diverting toilet, organic fertilizer, sensor-operated, sustainable sanitation, PET bottles, w*ater conservation, waste management, hygiene, resource utilization, composting.

1. Introduction

Currently, a global sanitation crisis persists, with staggering numbers highlighting the magnitude of the issue. Approximately one billion individuals resort to open defecation, while a staggering 2.5 billion people lack access to even the most basic sanitation facilities. In 2012 alone, it is estimated that 1.5 million lives were claimed by diarrheal diseases resulting from poor sanitation (Garcia-Fine, 2015). Diarrhea, one of the world's most prevalent diseases, is primarily caused by inadequate sanitation and accounts for over 846,000 deaths each year. Although progress has been made in providing improved sanitation facilities to a growing portion of the global population, extending access to better sanitation remains challenging for the 2.3 billion individuals residing in rural areas (Ignacio et al., 2018).

The dire state of sanitation in rural communities of India often goes unnoticed by urban residents. Alarmingly, out of the planet's 1.3 billion inhabitants, nearly 800 million lack access to toilet facilities. Open defecation continues to be a pressing issue associated with poor sanitation and inadequate toilet infrastructure. Diseases like cholera, diarrhea, and E. coli infections are transmitted through water contamination caused by open defecation. To address this pressing concern and achieve comprehensive sanitation nationwide, innovative approaches and strategies are imperative. Access to sanitary facilities should be a universal right, accessible in all regions of the country. It is essential to raise awareness among the rural population in India about the urgent need to improve their physical well-being. Expanding sanitation coverage to unprecedented levels within this population is crucial to realizing this vision (Shah et al., 2020).

Discharging excrement or fecal matter through sewer lines into rivers and lakes poses a significant threat to water supplies and human life. However, fecal waste contains valuable nutrients that can enhance soil fertility. Instead of polluting water bodies, it makes more sense to utilize fecal matter to enrich the soil and harness its nutrient content. This project proposes a novel sanitation technique that minimizes human involvement while upholding established sanitation standards.

Ensuring hygienic conditions after toilet usage is of utmost importance. Introducing sensors into the project plays a pivotal role in maintaining cleanliness. Restroom sensors are employed to automate toilet flushing and fragrance spraying. To address the issue of misuse of flushing systems by toilet users, sensors are incorporated to maintain consistent automated flushing, effectively cleaning the toilets. Additionally, sensors are employed for regular fragrance sprays, ensuring a pleasant smell in the facilities and mitigating any unpleasant odors caused by improper flushing practices.

The inclusion of PET (Polyethylene Terephthalate) bottles in this project represents a significant step towards environmental protection and the development of eco-friendly toilets. With the increasing population, PET bottle production has surged, but inadequate disposal practices have resulted in their widespread presence, littering the environment. When these bottles mix with the soil, they adversely affect soil fertility as they take around 450 years to decompose. Furthermore, plastic waste, including PET bottles, has become a pervasive problem in water bodies, causing harm to aquatic life and contributing to the deaths of over 1.1 million seabirds and other animals annually. By utilizing PET bottles, this project contributes to the preservation of nature.

Compared to other household tasks, toilet usage consumes significantly less electricity. A sustainable alternative to relying on generated electricity is harnessing solar energy. Solar power can generate ample electricity to meet most electrical needs, such as lighting and sensor operations. Utilizing freely available solar energy requires thoughtful consideration. Solar panels have been installed at top the toilet to provide the necessary electricity, effectively addressing the pressing issue of carbon emissions. The lighting system, flushing system, and odor removal system rely on this solar-powered sensor-based automation, which eliminates issues arising from user negligence and ensures efficient utilization of water and light while safeguarding the environment.

The global sanitation crisis is an ongoing challenge that demands innovative solutions to provide sustainable and efficient sanitation systems for communities worldwide. One such solution is the development of zero-waste toilets, which aim to address the issues of poor sanitation, water contamination, and environmental degradation. This chapter introduces an zero-waste toilet design known as the Sensor-Operated Urine Diverting Toilet that not only promotes sustainable sanitation practices but also facilitates fertilizer production through the recycling of waste materials. The incorporation of sensor technology and solar power in this design enhances its efficiency and reduces the environmental impact associated with traditional sanitation methods.

Access to proper sanitation facilities is a fundamental human right and a critical factor in promoting public health and well-being. However, the current global sanitation situation is alarming, with millions of people lacking access to safe and hygienic sanitation facilities (UNICEG ＆ ＷＨＯ, 2019). Inadequate sanitation contributes to the spread of diseases, particularly in low-income communities where open defecation is prevalent. Diarrheal diseases, for instance, claim the lives of hundreds of thousands of people annually, mainly due to poor sanitation and lack of access to clean water (Prüss-Ustün et al., 2014). Furthermore, the disposal of untreated human waste poses significant environmental risks, such as water pollution and soil degradation (Tilley et al., 2014).

Zero-waste toilets offer a promising solution to address the challenges of traditional sanitation systems. These toilets integrate environmentally friendly practices, resource conservation, and waste recycling, making them an effective and sustainable option for communities in need. By implementing zero-waste toilets, several benefits can be achieved, including improved public health, reduced water pollution, and the production of valuable resources, such as fertilizers (Crume, 2018).

The incorporation of sensor technology in the current toilet enables automated flushing, odor control, and maintenance functions. Sensors detect the presence of users and initiate the flushing process, reducing water consumption and promoting water conservation (Ray, 2017). Furthermore, sensors can be used to monitor the cleanliness of the toilet and automatically dispense cleaning agents or fragrances, ensuring a hygienic and pleasant environment for users (Aryza et al., 2022).

A key feature of the current toilet is the separation of urine from solid waste. Urine, rich in nitrogen, phosphorus, and potassium, can be collected separately and processed into a nutrient-rich liquid fertilizer through appropriate treatment methods (Simha and Ganesapillai, 2017). This process not only prevents the contamination of water sources but also offers a valuable resource for agricultural purposes, contributing to sustainable farming practices (Angeletti and Bjørseth, 2013).

The implementation of the current toilet brings numerous environmental benefits. Firstly, the diversion of urine reduces the load on wastewater treatment systems, decreasing energy requirements and treatment costs (Wilderer and Schreff, 2000). Secondly, the recycling of urine into fertilizer reduces the demand for synthetic fertilizers, which are often produced through energy-intensive processes and contribute to greenhouse gas emissions (Cordell et al., 2009). Furthermore, the utilization of solar power as the primary energy source minimizes the reliance on fossil fuels, mitigating carbon emissions and combating climate change (Shafiee and Topal, 2009).

The primary objective of this research is to explore the feasibility, efficiency, and effectiveness of the Sensor-Operated Urine Diverting Toilet as a sustainable sanitation solution. Specific research objectives include:

1. Investigating the performance and functionality of the toilet in terms of user satisfaction, water conservation, and waste management efficiency.
2. Assessing the environmental impact of the toilet, including its potential for reducing water pollution, carbon emissions, and reliance on synthetic fertilizers.
3. Examining the economic viability and cost-effectiveness of implementing the toilet in different contexts.
4. Identifying potential barriers to adoption and strategies for promoting the widespread use of zero-waste toilets in communities worldwide.

The following are the important parameters of the zero-waste toilet.

Fecal Waste: Human feces contain pathogens such as bacteria and viruses that can cause diseases (Prüss-Ustün et al., 2014). Unfortunately, access to proper sanitation, especially in low-income urban areas, is severely limited. Less than 10% of urban areas in low-income nations have access to sewer systems, and a significant portion of fecal waste is left untreated, posing serious health risks to the public and the environment (2019). Lack of funding, inadequate infrastructure, and limited space contribute to the absence of piped networks for sewage disposal and wastewater management (Tilley et al., 2014). When onsite sanitation facilities like pit latrines become full, fecal waste, known as fecal sludge, needs to be physically removed and transported to treatment facilities. However, there is potential to utilize treated fecal sludge as fertilizer in agriculture, improving soil health (Simha and Ganesapillai, 2017). Overcoming societal prejudice and lack of awareness is crucial in promoting the beneficial use of human waste, as it enhances soil fertility and reduces the negative impact of chemical fertilizers on soil acidification and salinization.

PET Bottles: The production of PET (Polyethylene Terephthalate) bottles amounts to 56 million tons annually, with approximately 30% of the global demand fulfilled by bottle production, primarily for beverages (Crume, 2018). Unfortunately, used PET bottles contribute significantly to plastic pollution, ranking high among the plastic debris found during beach clean-ups. Improper disposal of plastic bottles can exacerbate flooding issues in developing nations lacking proper waste management systems (Shafiee and Topal, 2009). PET's durability is both a strength and a weakness, as it takes around 450 years to fully degrade, occupying valuable landfill space. This project aims to reduce waste generated by reusing PET bottles and minimizing their disposal.

Sensors: In this project, sensors play a vital role in maintaining hygienic conditions and optimizing resource usage. Motion sensors installed in toilets detect human presence and trigger automatic flushing, resulting in increased water efficiency and reduced cleaning costs. Smart toilets equipped with sensors can reduce water usage by up to 80% by automatically flushing and cleaning after each use. These sensor-based systems not only improve cleanliness and hygiene but also contribute to energy efficiency and environmental sustainability through smart lighting features (Ray, 2016). Additionally, sensors are employed to ensure a pleasant odor in the restroom area, with regular spraying to maintain a fresh and comfortable environment (Aryza et al., 2022).

Nutrient Recovery: Rather than considering waste materials like feces and urine as pollutants, this project recognizes their potential as valuable resources. These waste materials contain essential nutrients that can be effectively recovered and utilized to enhance the agricultural sector. By combining fecal waste with organic waste, organic chemicals, wheat bran, and sawdust to reduce moisture, and utilizing a composter to accelerate the composting process, a finished product can be obtained. This nutrient-rich compost can be used as fertilizer when exposed to a temperature of 35-40 degrees Celsius. By utilizing this recovered nutrient from waste as fertilizer, farmers can reduce their reliance on chemical fertilizers, which often have negative effects on human health and the environment (Simha and Ganesapillai, 2017).

Societal Benefits: By efficiently utilizing waste discharged from toilets and recovering its nutrients for fertilizer production, the project promotes sustainable farming practices. This reduces reliance on artificial fertilizers and harmful chemicals, resulting in more effective and environmentally friendly fertilizers. Additionally, farmers can potentially generate income by selling these nutrient-rich fertilizers (Simha and Ganesapillai, 2017).

The following raw materials have been used to manufacture Zero-waste toilet.

Mild Steel: Mild steel is a type of carbon steel with low carbon content. It is popular due to its weldability and machinability, making it suitable for various applications. Mild steel is often used in the construction of steel frames and in manufacturing roofing materials like M.S. Sheets.

Plaster of Paris (POP): Plaster of Paris is a white powder that, when mixed with water, forms a solid mass called gypsum. It is used to improve the smoothness of surfaces and is commonly used for creating molds and casts. In the context of the proposed toilet, gypsum plaster (POP) is used for finishing toilet pan mold.

PVC: PVC stands for polyvinyl chloride, and it is a widely used polymer known for its versatility. PVC has many applications in various industries. It is durable and long-lasting, making it a popular choice for construction purposes.

PET Bottles: PET (Polyethylene Terephthalate) bottles are a type of plastic bottle commonly used for packaging beverages and other products. However, the excessive use of plastic bottles has become an environmental concern. In the context of the toilet project, PET bottles are reused as building material, specifically for constructing walls. These bottles, known as ECO-BRICKS, are eco-friendly and help reduce pollution.

Bricks: Bricks are one of the oldest and most common building materials. They are typically made from burnt clay and have properties such as durability, strength, and resistance to moisture and erosion. Bricks are used for various construction purposes, including walls, septic tanks, foundations, and flooring.

Cement: Cement is a binder used in construction to bind other materials together. It is mainly used in concrete and mortar. Cement is manufactured through a chemical process that combines calcium, silicon, aluminum, iron, and other ingredients. Ordinary Portland cement is a commonly used type of cement in construction.

Aggregate: Aggregates are natural particles obtained through mining processes. They make up a significant portion of concrete, providing bulk and compressive strength. Coarse aggregates, such as gravel and crushed stone, are used for making concrete, while fine aggregates, such as sand, are used for both concrete and filtration purposes.

Nylon Mesh: Nylon mesh is a type of plastic-based fiber that is extruded into strands of various sizes and thicknesses. It is known for its filtration properties. In the context of the toilet project, 120-

micron nylon mesh is used to separate flush water and feces and purify the flush water.

Charcoal: Charcoal is a black carbon residue produced by heating wood or other organic materials in the absence of oxygen. Activated charcoal, in particular, has a high adsorption capacity and is used for filtration purposes. In the toilet project, activated charcoal is used to enhance the rate of filtration.

Water: Water is an essential component in construction activities. It is used for various purposes such as preparing mortar, mixing cement concrete, curing work, and creating a water-cement paste. The quality of water used in construction affects the quality of mortar or concrete.

Industrial Sand: Industrial sand is high-purity silica sand with uniform grain size. It is used for filling PET bottles in the toilet project. The use of industrial sand helps reduce industrial waste and provides additional strength to the walls of PET bottles.

Tiles: Tiles are thin coverings made from materials such as ceramic, stone, metal, clay, or glass. They are commonly used for covering internal walls and flooring in construction.

Fiber Glass Resin: Fiberglass resin is a synthetic material that is created by combining alcohols and organic acids. It can be prepared in various forms, including gels, films, and liquids. When used in the manufacturing process of a toilet pan, the resin is typically in liquid form and is catalyzed before being applied to the fiberglass mold. Once applied, it undergoes a chemical reaction known as thermosetting, which involves curing and bonding to the fiberglass. During this process, a significant amount of heat is generated. The resin gradually cures, starting as a jelly-like consistency within 10-20 minutes and becoming hard within 30-40 minutes at room temperature.

Special Wax (Releasing Agent): A releasing agent, such as special wax, is a critical component used in the manufacturing process of molds. It creates a barrier between the mold surface and the substrate, facilitating the separation of the cured part from the mold. Without a releasing agent, the substrate would adhere to the mold surface, resulting in difficulties during clean-up and a loss in production efficiency.

Hardener: In certain mixtures, a hardener is added to increase the resilience of the material once it sets. In other cases, a hardener serves as a curing component. A hardener can function as either a reactant or a catalyst during the chemical reaction that occurs when the mixture is mixed. It may also be referred to as an accelerator, as it speeds up the curing process.

Marble Powder: Marble powder is a fine powder obtained as a by-product during the sawing and shaping of marble. It has been studied from a chemical and physical perspective to determine its potential use as a mineral addition in mortars and concretes, particularly for self-compacting concrete. Marble powder exhibits a high Blaine fineness value, indicating its fineness, with a significant portion of particles being smaller than 50 μm. Various cement pastes were prepared using marble powder, with and without the addition of an acrylic-based superplasticizer, to evaluate its effects on mechanical behavior. The substitution of sand with 10% marble powder showed maximum compressive strength while maintaining similar workability compared to mixtures without marble powder.

Fiber Mat: A fiber mat is a type of biodegradable fibrous material that is woven into mats of different sizes and thicknesses. It is commonly composed of coconut fiber and possesses certain characteristics such as uniform fiber dispersion, a smooth surface, a soft hand-feeling, low binder content, fast resin impregnation, and good mold obedience. Fiber mats are often used in various applications, including construction, as reinforcement, or for providing added strength and durability to materials.

Motion Sensor: Motion sensors in toilets detect movement and enable touchless operations. They automate flushing by detecting when a person approaches or moves away, triggering an automatic flush mechanism. Motion sensors can also control toilet seats, lifting them when someone approaches and lowering them when they move away. Additionally, they facilitate touchless handwashing by activating water flow and soap dispensers when hands are detected beneath the sensors. These sensors enhance hygiene by eliminating the need for manual interaction with toilet fixtures, reducing the spread of germs, and providing a convenient and sanitary experience for users.

Heating system: To accelerate the early decomposition of fertilizer, a heating system can be employed. This system typically consists of heating elements or a heat source that raises the temperature within the fertilizer storage or decomposition area. The heat promotes microbial activity, which speeds up the breakdown of organic matter in the fertilizer. The heating system may utilize electric heaters, steam coils, or hot air blowers to generate the necessary warmth. By maintaining an optimal temperature range, the heating system creates favorable conditions for microbial activity, enhancing the decomposition process and ensuring the fertilizer becomes readily available for plant uptake in a shorter time frame.

2. Materials and methodology:

2.1Toilet pan (urine diverting pan):

Figure 1: Toilet Pan

Figure 1 depicts a toilet pan. A urine diverting toilet pan, commonly used for compost production and safe sanitation, is made from Fiber Glass Resin due to limitations in ceramic manufacturing requirements and material availability. The manufacturing process involves several steps:

Figure 2: Crafting toilet pan

The process of crafting the toilet pan involves several steps to ensure its quality and functionality. Figure 2 depicts the making toilet pan. First, the selection of the appropriate size for the toilet pan is crucial to fit the intended space and purpose. Following this, a layer of special wax is applied to the pan, acting as a releasing agent to provide surface smoothness and facilitate easy removal. This wax layer requires about 30 minutes to dry. Next, a solution of Fiber Glass Resin is prepared, and mixed with cobide to provide strength to the pan while achieving the desired white color. The addition of marble powder is an option to fine-tune the solution's density. To control the setting time, a hardener is added to the solution, and the quantity can be adjusted as needed.

The entire solution is then carefully poured into the mold, ensuring precision in the manufacturing process. To enhance the pan's strength and durability, a layer of fiber mat is applied. The pan is allowed to set for approximately 30 to 40 minutes, ensuring that it takes on the desired form. A finishing layer of plaster of Paris (POP) is then applied to the pan, further contributing to its surface smoothness. Finally, the pan is painted white to achieve its final aesthetic appearance, resulting in a well-crafted and functional toilet pan ready for use.

3. Sensor technology:

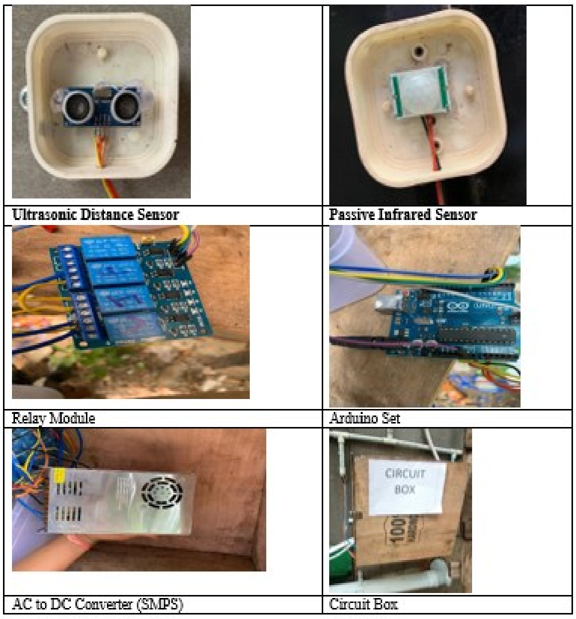


Figure 3: Toilet pan sensor configuration

When a person enters the toilet, a sophisticated system of sensors comes into play to ensure a convenient and efficient experience. Figure 3 demonstrations Toilet pan sensor configuration. As soon as someone steps inside, motion sensors detect their presence and trigger a series of actions. First and foremost, the light illuminates automatically, ensuring adequate visibility within the restroom.

Now, let's consider the flushing mechanism. If the person finishes toilet activity and leaves the toilet within three minutes, the flush system activates without any additional input. This helps conserve water, as a single flush utilizes six liters of water. However, if the individual needs more time in the restroom and stays beyond three minutes, a unique feature comes into play. To initiate the flush, they simply need to place their hand in front of an ultrasonic distance sensor for a mere five seconds. This ensures that water is used judiciously, aligning with modern efforts to save water resources. Moreover, for added convenience, the system not only triggers the flush but also starts the jet function simultaneously. This ensures a thorough and hygienic cleaning experience for the user.

In summary, this system seamlessly integrates motion sensors, lighting control, and water-saving features to enhance both convenience and sustainability. Whether you're in and out quickly or require a bit more time, this system ensures a comfortable and eco-friendly visit to the toilet.

3.1 Operational units of sensor:

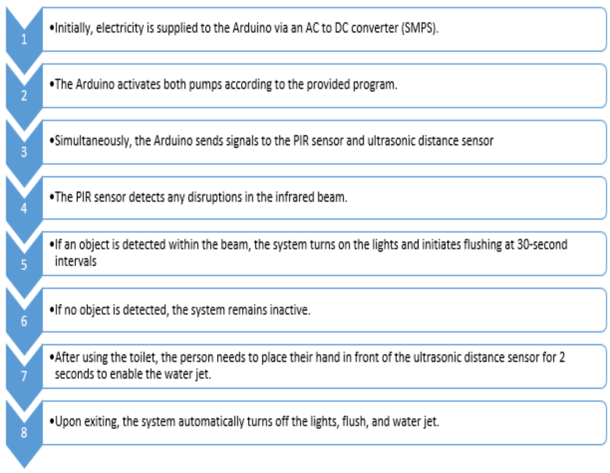


Figure 4: Operation of sensor

In this automated toilet project, ultrasonic sensors detect user presence and proximity, triggering the flushing mechanism when someone approaches or leaves the toilet. When a user enters, the ultrasonic sensor measures distance; if the user moves away, it triggers a flush. PIR sensors are employed for intelligent lighting control, illuminating the area when motion is detected. Furthermore, a separate PIR sensor is used to activate a light switch, ensuring convenient hands-free operation. This integrated system enhances hygiene and convenience, conserving water through precise flushing and promoting energy efficiency with responsive lighting control. Figure 4 depicts sensor operation.

In the model, sensors are incorporated to enhance functionality and reliability while reducing physical contact and potential bacterial infections. Various sensors are utilized for different purposes, including automatic flushing and occupancy detection. The flushing sensor automatically flushes the human waste. Another sensor is responsible for determining the amount of water to be dispensed based on the duration of toilet usage. If the person spends more time, a larger amount of water will be dispensed, while less water will be used for shorter durations. Additionally, sensors are employed to maintain cleanliness by periodically spraying water on the floor for disinfection. This sensor-based approach improves energy efficiency and sanitation in the toilet. Table 1 lists the sensor's technical parameters.

Table 1: Technical specifications of sensor

Technical specifications of ultrasonic distance sensor (HC SR04)		Technical specifications of Passive Infrared Sensor	
Parameter	Value	Parameter	Value
Operating Voltage	DC 5V	Operating Voltage	DC 5V – 12V
Operating Current	15mA	Operating Current	40mA
Operating Frequency	40KHz	Operating Frequency	8-14 KHz
Max Range	4m	Max Range	5m
Min Range	2cm	Min Range	0.5m
Ranging Accuracy	3mm	Measuring Angle	110-180 degrees
Measuring Angle	15 degrees	Dimension	50 x 50 x 25mm
Dimension	45 x 20 x 15mm	-	-

3.2 Separation & collection unit:

The separation unit consists of a tank with two compartments for separating flush water and feces. One compartment collects the filtered flush water, while the other compartment holds the feces. The collected feces are then transferred to a drying tank, where they undergo a 15-day drying process facilitated by a heater. The heater maintains a temperature between 40 to 45 degrees Celsius. The PCC tank is constructed using regular burnt clay bricks and PCC materials, and polyurethane waterproofing chemicals are applied inside the tank to prevent water penetration and ensure its integrity.

Before the collection tank, there is an additional tank called the M.S. (Mild Steel) tank, which is positioned above the PCC tank and beneath the outlet of toilet pipes. The M.S. tank is installed on an M.S. stand in such a way that it tilts towards the side with more weight when feces fall into it. Inside the M.S. tank, both nylon mesh and M.S. mesh are fitted inclined at a 45-degree angle. The M.S. mesh provides support to the nylon mesh. The purpose of the M.S. tank is to filter the flush water and feces, with the bottom of the tank remaining open to collect the flush water separately.

The dimensions of the M.S. tank are as follows in **Figure 5**.

- Size: 1'6" x 1'6" x 1'6"

Separation tank | Inclined mesh with two layers

Figure 5. Dimension of M.S tank

4. Filtration unit

The filtration unit is a complex system comprising various integral components and layers, each playing a crucial role in the water purification process. At its base lies the large gravel layer, characterized by gravel sizes ranging from 16mm to 32mm. Positioned above this layer is the fine gravel layer, featuring smaller gravel sizes in the range of 4mm to 8mm. Further up the filtration hierarchy is the fine sand layer, which consists of sand particles with sizes ranging from 0.4mm to 0.6mm. At the very top of this intricate setup is the layer of anthracite coal grains, comprising coal particles ranging from 0.5mm to 1.2mm in size.

Collectively, these layers work in concert to create the filter bed, a composite structure vital for water treatment. The filter bed, spanning a size range from 0.6m to 3m, ensures that the water undergoes a comprehensive purification process. To facilitate the flow of water, the filtration unit is equipped with inlet and outlet points. At the top, an inlet serves as the entry point for unfiltered water, while an outlet is positioned for the removal of backflush water. Simultaneously, at the bottom, an outlet facilitates the extraction of filtered water, while an inlet is designated for the passage of backflush water. This multifaceted design allows the filtration unit to effectively and efficiently purify water, making it an indispensable component in water treatment systems. **Figure 6** shows the filtration unit.

Figure 6. Filtration unit

4.1 Process of manufacturing & assembling of zero-waste toilet

The process of creating a zero-waste toilet involves several essential steps aimed at sustainability and functionality. To start, PET bottles are collected from various sources like local restaurants, bars, canteens, and scrap merchants, serving as the primary material for constructing the toilet wall. These bottles, commonly used for beverage packaging, are highly recyclable, contributing to reduced plastic waste and emissions. Figure 7 depicts the assembly of a zero-waste toilet.

Figure 7. Assembling zero-waste toilet

In the second step, the PET bottles are fortified with industrial sand to enhance their strength and minimize the risk of air voids. This approach not only provides structural integrity to the bottles but also contributes to the reduction of industrial waste. Moving on to the third step, the installation of the toilet's frame provides the necessary structural support and cohesion for the entire zero-waste toilet. Typically constructed from sturdy materials like metal, the frame is designed to withstand the toilet's weight and usage.

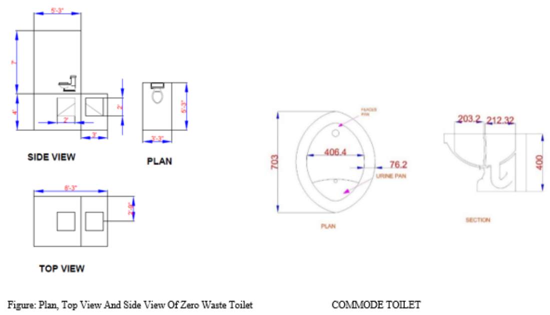
Following the frame installation, the toilet pan is put in place. The toilet pan, made of durable materials such as ceramic, serves as the receptacle for human waste before flushing. It's seamlessly integrated into the plumbing system to ensure proper waste flow and flush water control. Step five introduces the integration of sensors to enable touchless operation. These sensors detect human presence, control lighting, initiate flushing, and determine toilet seat occupancy. They also activate features like water jets for personal hygiene and odor-removing sprays. Furthermore, the zero-waste toilet's floor is self-cleaned using a water jet, and the entire system operates on solar power.

The next step involves a sophisticated collection system for feces. The flush water and human waste enter a separation tank beneath the toilet, with compartments designed for water removal and separated water storage. A filtration tank equipped with a 120-micron nylon mesh separates water from the flush material. Once the tank reaches its capacity, it tilts, transferring separated feces to a storage tank, where water-filtered feces undergo a 15-day drying process to remove odor and bacteria. To reuse separated flush water, step seven introduces an activated charcoal filter with multiple layers of filter bed, effectively removing fine particles. The filtered water can be repurposed for gardening, and a backflush water pipe allows for filter chamber cleaning when needed.

Lastly, step eight addresses the composting of fecal sludge, a controlled aerobic process that transforms organic materials into a nutrient-rich soil amendment. Dried human feces and bio additives like sawdust and flour mill waste are used, along with a composter (bacterial medium). This composting process follows specific temperature parameters to ensure proper decomposition while considering the nutrient values of the resulting compost, specifically Nitrogen, Phosphorus, and Potassium (NPK). The comprehensive zero-waste toilet system combines sustainability, resource efficiency, and functionality, representing a forward-thinking approach to waste management and sanitation.

4.2 Constructional features of toilet

The below **figure 8** shows the construction features of the Toilet.



DOI: 10.6977/IJoSI.202406_8(2).0006
P. Abhijeet, S. Sanjeev, et al./Int. J. Systematic Innovation, 8(2), 70-86 (2024)

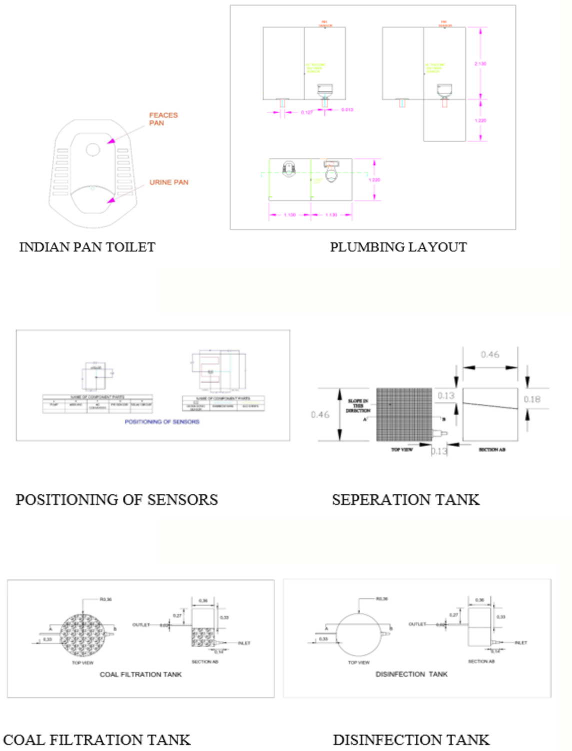


Figure 8. Construction features of Toilet

4.3 Flow diagram of operation

Below **Figure 9** shows the flow diagram of the operation.

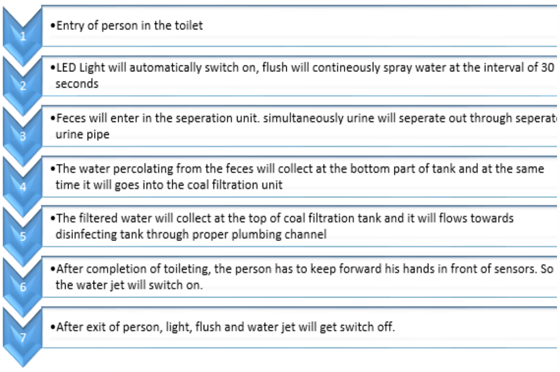


Fig 9. Flow diagram of operation

5. Results and discussion

5.1 Toilet pan (urine diverting pan)

The urine-diverting pan, a distinctive feature of this design, effectively separates urine from feces, offering several advantages. First and foremost, it allows for the easy collection of clear urine through the toilet outlet. This clear urine contains valuable nutrients and facilitates the extraction of urea, making the process more efficient. Additionally, the separated fecal sludge can be repurposed for fertilizer production, provided it maintains controlled moisture content. The urine separation plays a vital role in achieving this.

Furthermore, the pan has been engineered to withstand the weight of a person using the toilet, ensuring its durability and reliability. This urine-diverting feature is incorporated into both Indian and commode pans, extending its applicability to both rural and urban users. The flushing and water jet mechanisms are integrated into these pans, mirroring the convenience of traditional ceramic pans. Manufacturing the pan involves careful steps, including proper mixing of raw materials and applying heat to the prepared mixture to ensure optimal strength. Finally, the pan's dimensions are thoughtfully designed to ensure comfort and usability for individuals.

5.2 Sensor technology

Incorporating sensors into the toilet system streamlines its operation, rendering it completely touchless and promoting superior hygiene maintenance. This technology holds particular significance in mitigating the spread of diseases often associated with conventional toilet systems. By implementing touchless sensors in both the flush system and the water jet mechanism, water consumption is notably reduced. Without sensor technology, a single flush typically consumes 10 liters of water, whereas, with sensors, it efficiently manages to dispense just 6 liters per flush. This water-saving feature extends to the water jet system as well.

Water-repellent sensors are employed, ensuring optimal functionality even in the presence of water. This robust design prevents any system interruptions. A circuit box is positioned on the rear exterior of the toilet, housing essential components such as the relay module and Arduino system. This box is thoughtfully enclosed in a wooden casing to shield it from the effects of weathering. The meticulous organization of wiring within the system keeps all sensor functions running smoothly and efficiently.

5.3 Separation and collection unit

The separation unit efficiently divides urine from fecal sludge, with the inclined mesh facilitating the percolation of wastewater and its flow to the bottom.

This design ensures that feces remain in a dry state, simplifying the organic fertilizer manufacturing process. The system incorporates two meshes within the same tank: one constructed from mild steel and the other from nylon fabric. The mild steel mesh prevents solid residues from entering, while the nylon fabric prevents the passage of fine, powdered materials. This dual mesh approach significantly enhances the tank's ability to retain a maximum amount of residue at the upper section.

The bottom part of the tank is linked to an outflow mechanism, which directs wastewater to a disinfection tank. This tank features a handle on one side, enabling a 180-degree rotation. The handle is skillfully designed to maintain a tight seal during rotation, facilitating waste collection. The collection tank includes materials that aid in the early decomposition of the mixture and can effectively control odors through the incorporation of organic minerals. The outflow pipe is strategically attached to minimize the accumulation of wastewater at the bottom, and the plumbing system is thoughtfully engineered to ensure that the rotating motion does not disrupt the flow of wastewater.

5.4 Filtration unit

The filtration unit is a two-part system, consisting of a charcoal filtration tank and a disinfection tank. The first tank effectively separates solid residues, while the second tank is designed to remove smaller dissolved content. In the charcoal filtration tank, the presence of solid residue is prevented from passing through due to the action of charcoal. The quantity of charcoal used has been meticulously determined through laboratory testing, involving the flow of a small amount of wastewater through it. After several iterations, it was determined that 6 kg of charcoal is required for efficient filtration. It's important to note that this charcoal needs to be replaced after every 500 liters of water flow. Considering that each person uses approximately 10 liters of water per toilet use, this means that charcoal replacement is needed after about 50 usages. The charcoal primarily consists of carbon, which has an affinity for binding residual content. The system operates on a gravitational flow principle, allowing solid residues to settle at the bottom, while the lighter clear water flows upward.

The outlet of this tank is connected to the disinfection tank, which employs chlorine as a disinfectant. Post-disinfection, the water can be used for flushing or irrigation purposes, but it is not suitable for drinking or bathing. If rigorous disinfection processes are applied, the water can eventually be safe for drinking, although this depends on people's perceptions and attitudes towards water quality.

5.5 Quantitative analysis

The container's volume is precisely 0.095 cubic meters, a calculation based on the tank's dimensions, measuring 457mm x 457mm x 457mm. Within this container, there are two distinct sections: the upper part, designated for feces accumulation, occupies 0.0285 cubic meters, while the lower part, intended for wastewater, encompasses 0.0665 cubic meters. However, due to the drain outlet's location at the bottom, only 50.8mm in height is available for water storage in the lower section.

An individual typically excretes approximately 200 grams of feces. Feces density ranges from 1000 to 1300 kg per cubic meter. This translates to a feces volume of approximately 0.0002 cubic meters per person. By dividing the volume of the upper part of the tank by the volume of feces, we can estimate that the tank can accumulate waste from approximately 140 people, resulting in a total feces weight of 28 kilograms.

To prevent overflow, the tank cannot be filled to its full capacity, requiring a 5cm headspace to be maintained at the top. Consequently, 16 liters of water will remain in the lower part of the tank.

Considering the weight of the feces, the weight of the water, and the self-weight of the tank, the total weight of the tank is 58 kilograms. This calculation ensures that the system operates effectively and can manage waste from a considerable number of individuals while maintaining proper safety margins to prevent any potential issues like overflow.

5.6 Calculation of air requirement for fertilizer production

For preparation of organic fertilizer, aerobic process is adopted. For smooth conduction of the aerobic process, minimum 10% oxygen is required. Calculating the air requirement for fertilizer production from fecal sludge is a fundamental step in ensuring the efficient aerobic digestion of organic matter. This process involves estimating the amount of oxygen needed to facilitate the decomposition of organic materials within the sludge. The calculation is typically based on the organic content present in the sludge and the application of stoichiometric ratios. The stoichiometric ratio used depends on the specific composition of organic matter in the sludge.

For instance, carbohydrates typically require about 6 grams of oxygen per gram of organic matter, fats need approximately 5.3 grams of oxygen per gram of organic matter, and proteins demand around 4.57 grams of oxygen per gram of organic matter. By determining the organic content and applying the appropriate stoichiometric ratio, the air requirement can be quantified in terms of kilograms of oxygen needed for the aerobic decomposition process.

This calculation serves as a crucial foundation for designing and operating the system efficiently, ensuring that the right amount of air is supplied to facilitate the decomposition of organic matter, which ultimately leads to the production of high-quality fertilizer. Accurate calculations are imperative in optimizing the process and resource utilization while minimizing environmental impact.

5.7 Economic Analysis

Table 2. Economic analysis of materials

Sr. No.	Materials/ Mechanical part/ Object
1	Ceramic powder
2	Plastic bottles
3	Soil
4	Shed net
5	Toilet pan mould
6	Fiber Toilet pan (Indian)
7	Fiber Toilet pan (Commode)
8	Labor for manufacturing toilet pan and mold
9	Fabrication cost for wall frame
10	Plumbing cost
11	M.S. sheets used for septic tank
12	The overall mechanism of septic tank
13	Labor for construction of Septic tank
14	Sensors
15	Aggregates
16	Cement
17	Labor for construction of toilet block
18	Solar Panels

Table 2 shows Economical analysis of materials. For overall toilet preparation, approximately 90,000/- cost is required. This cost includes fabrication charges, sensor, pump, preparation of toilet pans, plumbing & electrification appliances etc. Firstly, 1 kilogram of ceramic powder, priced at 225 Rs/- per kilogram has been used. Additionally, 400 units of plastic bottles are needed, amounting to 300 RS/-. For the construction and landscaping aspects, 1 brass of soil is necessary, with a cost of 4000 RS/-. To provide shelter and protection, we'll be using a 35-meter by 13-meter shed net, which costs 450 RS/-.

The remaining items on the list include specific components and labor costs related to the construction of a toilet block and septic tank, as well as the installation of solar panels. These components encompass fiber toilet pans (Indian and Commode), labor for manufacturing toilet pan and mold, fabrication costs for the wall frame, plumbing expenses, M.C. sheets for the septic tank, the overall mechanism of the septic tank, labor for constructing the septic tank, sensors, aggregates, cement, and labor for the construction of the toilet block.

6. Conclusion

The research conducted on the zero-waste toilet, a sensor-operated solar-based urine diverting toilet, has revealed several positive outcomes regarding its design, functionality, and potential benefits. The findings of this study contribute to the understanding of sustainable sanitation systems and their implications for environmental, developmental, and sustainable practices.

The utilization of repurposed plastic PET bottles for constructing the walls of the zero-waste toilet presents a successful approach to reducing plastic waste. By repurposing these bottles, the zero-waste toilet not only contributes to environmental sustainability but also promotes local material availability and sustainable construction practices. The integration of sensors in the zero-waste toilet has proven to be effective in enhancing user convenience and efficiency. The touchless operation provided by the sensors eliminates the need for manual flushing and enhances the overall user experience. The sensors' ability to detect human presence, control lighting, initiate flushing, and determine toilet seat occupancy ensures a seamless and convenient operation. Moreover, the incorporation of water jets for personal hygiene and odor-removing sprays further enhances the cleanliness and comfort of the zero-waste toilet. The urine separation capability of the zero-waste toilet has significant implications for waste management and resource utilization. The specially designed pan effectively separates urine from feces, improving waste management practices and minimizing potential odors. With some models being able to separate up to 80% of urine within the pan, the zero-waste toilet presents an opportunity to utilize urine as a valuable resource for agricultural purposes, thereby contributing to sustainable agriculture and nutrient recycling.

Water conservation is a notable achievement of the zero-waste toilet. The automated flushing system, controlled by the sensors, ensures that water is used efficiently and only when required. By activating the flushing mechanism only when the user has finished using the toilet, the zero-waste toilet minimizes water wastage and promotes responsible water management practices, addressing water scarcity concerns and supporting sustainable water use. The hygienic qualities of the zero-waste toilet are commendable. The touchless operation, along with the water jets and flush mechanisms, reduces the risk of germ transmission and contamination. The design of the zero-waste toilet incorporates easy-to-clean surfaces and materials, further enhancing its hygienic attributes and ensuring a clean and safe user experience. The durability and long lifespan of the zero-waste toilet make it a sustainable solution for sanitation needs. The automated features reduce wear and tear, resulting in reduced maintenance requirements and prolonged usability compared to traditional toilets. This durability contributes to the zero-waste toilet's sustainability and cost-effectiveness in the long run, promoting its viability as a long-term sanitation solution.

The zero-waste toilet's ability to transform human feces into organic fertilizer showcases its potential to address waste management challenges and promoting sustainable agricultural practices. By diverting feces into a separate storage tank and employing a filtration system, the zero-waste toilet separates solid waste from liquid content effectively. The separated solid waste can be processed into organic fertilizer through composting, providing a valuable resource for soil enrichment and sustainable agricultural practices. This closed-loop system reduces reliance on synthetic fertilizers, promotes circular economy principles, and supports environmental sustainability. It is important to acknowledge the limitations of the zero-waste toilet as well. The implementation and maintenance of these advanced systems may require specialized expertise, potentially limiting accessibility and increasing reliance on trained professionals. The initial investment required for installing zero-waste toilets may be higher compared to traditional toilets, which can pose financial challenges for certain individuals or communities. Additionally, the maintenance of zero-waste toilets may demand additional efforts due to their complex automated systems. Overall, the research findings demonstrate that the zero-waste toilet has the potential to address various environmental, developmental, and sustainability challenges associated with traditional sanitation systems. Its advantages in terms of plastic waste reduction, convenience, water conservation, hygiene, and resource utilization make it a promising solution for sustainable sanitation. Further research and implementation efforts are necessary to

Merits

Zero-waste toilets offer numerous merits that contribute to improved sanitation and environmental sustainability. Firstly, they are equipped with a fully automated sensor for the flushing system, eliminating the need for manual flushing and promoting convenience and efficiency. Additionally, these toilets are designed to save water, addressing water scarcity concerns by utilizing water-saving mechanisms. Zero-waste toilets also play a significant role in enhancing hygiene and sanitary conditions. They provide a fully contactless experience, minimizing the risk of germ transmission and promoting cleanliness. Moreover, these toilets experience less wear and tear due to their automated features, resulting in reduced maintenance and longer lifespan.

One of the notable benefits of automatic toilets is their ease of use. The automated functions streamline the user experience, making them accessible to a wide range of individuals. Furthermore, zero-waste toilets promote environmental sustainability by transforming feces into compost, providing a valuable resource for soil enrichment. They also incorporate water reuse systems for gardening, maximizing the utilization of available resources and reducing water waste.

The construction of Zero-waste toilet walls using plastic bottles is a notable advantage, as it contributes to the reduction of plastic pollution. By repurposing these bottles, the toilets actively address environmental concerns associated with plastic waste. Additionally, zero-waste toilets feature urine separation capabilities, with some models capable of separating up to 80% of urine in the pan itself. This helps in the efficient management of waste and reduces potential odors in the toilet area. Users of Zero-waste toilets also experience enhanced comfort, as these toilets are designed to provide a high level of comport during use. In terms of sanitation, zero-waste toilets ensure proper cleanliness by incorporating effective flushing mechanisms and providing a hygienic environment for users. Furthermore, these toilets offer a long lifespan, providing a durable and sustainable solution for sanitation needs. Notably, in the case of Indian pan toilets, zero-waste toilets address the challenge of bacterial infection transmission, as their design minimizes the spread of bacteria.

Demerits

Zero-waste toilets, while offering several merits, also have certain demerits that should be taken into consideration. Firstly, the operation of these toilets may require expertise, making them potentially challenging for individuals who are not familiar with their automated features. Additionally, the setup of Zero-waste toilets also requires specialized knowledge, which can limit their accessibility and increase reliance on trained professionals. One notable drawback is the higher initial investment required for Zero-waste toilets compared to traditional toilets. The advanced technologies and eco-friendly materials used in their construction contribute to the increased cost. Furthermore, zero-waste toilets typically require more maintenance due to their complex automated systems, which may involve periodic checks and repairs.

Sensors in zero-waste toilets may not always flush immediately when desired, as they operate on preset timings. This can cause inconvenience to users who expect immediate flushing. Moreover, there is a risk of dirty water splashing onto the user's bottom if the toilet flushes while they are still sitting, which can be unpleasant and unhygienic. Using this particular toilet requires a certain level of expertise due to various factors. Firstly, setting up the toilet itself demands specialized knowledge. Additionally, the initial investment for this toilet is relatively high compared to traditional options. Maintenance is also a concern, as it requires more attention.

The sensors in this toilet may not always respond as desired, sometimes delaying the flush and causing inconvenience. Moreover, there is a risk of dirty water splashing onto the user if the flush occurs while they are seated, which can be unpleasant. This can also be a source of fear for some children, making them hesitant to use it. Accidental drops can result in objects being flushed away permanently, which is a potential drawback. A broader issue is people's limited perspective on innovation, which can hinder the adoption of such advanced toilet systems. Separation of urine from feces is not complete, as approximately 20% remains mixed. Stopping the process when the feces tank is full can be challenging, particularly if someone is currently using the toilet.

Water-repellent sensors are essential for this system, but they come at an additional cost. Furthermore, efficient fertilizer production technology needs to be developed by the user to make the most of the waste. In terms of cost, this toilet is more expensive than traditional ones. Additionally, the production of ceramic toilets relies on molds that are not feasible for small-scale production due to the distance of major factories. Cleaning these toilets can be a more difficult and time-consuming task, and the plastic walls lack sufficient strength. Furthermore, filtering flush water in this system takes more time than standard toilets.

The concept of zero-waste toilet, a sensor-operated solar-based urine diverting toilet, presents a promising solution to overcome the limitations observed in traditional sanitation systems. This research paper has explored the design and functionality of the zero-waste toilet, highlighting its potential benefits in terms of convenience, water conservation, hygiene, and environmental sustainability.

One of the key advantages of the zero-waste toilet is its utilization of repurposed plastic PET bottles for constructing the walls. By repurposing these bottles, the zero-waste toilet actively contributes to reducing plastic waste and addresses environmental concerns associated with plastic pollution. This innovative approach showcases the potential for using locally available materials in sustainable construction practices. The integration of sensors in the zero-waste toilet enables touchless operation, eliminating the need for manual flushing and enhancing user convenience and efficiency. These sensors are designed to detect human presence, control lighting, initiate flushing, and determine toilet seat occupancy. Additionally, the sensors activate water jets for personal hygiene and trigger odor-removing sprays, promoting a clean and hygienic environment. The entire system operates on solar power, further enhancing its sustainability and reducing its reliance on conventional energy sources.

An important feature of the zero-waste toilet is its urine separation capability. By incorporating a specially designed pan, the toilet efficiently separates urine from feces, improving waste management and minimizing potential odors. Some models of the zero-waste toilet can separate up to 80% of urine directly within the pan, reducing the amount of waste that needs to be processed further. This urine diversion system not only contributes to better waste management but also presents an opportunity for utilizing urine as a valuable resource for agricultural purposes. Water conservation is another significant advantage offered by the zero-waste toilet. The automated flushing system, controlled by the sensors, ensures that water is used efficiently and only when necessary. The zero-waste toilet minimizes water wastage by providing a touchless experience and activating the flushing mechanism only when the user has finished using the toilet. This feature addresses water scarcity concerns and promotes responsible water management practices.

In terms of hygiene, the zero-waste toilet provides a high level of cleanliness and minimizes the risk of germ transmission. The touchless operation, along with the water jets and flush mechanisms, ensures that users have a fully contactless experience, reducing the potential for contamination. Additionally, the design of the zero-waste toilet incorporates easy-to-clean surfaces and materials, further enhancing its hygienic qualities. The zero-waste toilet offers a durable and long-lasting solution for sanitation needs. Its automated features reduce wear and tear, resulting in reduced maintenance requirements and a longer lifespan compared to traditional toilets. This durability contributes to the zero-waste toilet's sustainability and cost-effectiveness in the long run.

One of the most significant advantages of the zero-waste toilet is its ability to transform human feces into organic fertilizer. By diverting feces into a separate storage tank and employing a filtration system, the zero-waste toilet effectively separates solid waste from liquid content. The solid waste undergoes a drying process to remove odor and bacteria, while the liquid content can be reused for flushing or other purposes. The separated solid waste can be further processed into organic fertilizer through composting, providing a valuable resource for soil enrichment and sustainable agricultural practices. This closed-loop system not only addresses waste management but also contributes to environmental sustainability by minimizing the reliance on synthetic fertilizers. While the zero-waste toilet offers numerous merits, it is essential to acknowledge its demerits as well. The implementation and maintenance of these advanced systems may require specialized expertise, potentially limiting accessibility and increasing reliance on trained professionals. The initial investment required for installing zero-waste toilets may also be higher compared to traditional toilets, which can pose financial challenges for some individuals or communities. Maintenance of zero-waste toilets may demand additional efforts due to their complex automated systems.

Future Scope

The research conducted on the zero-waste toilet has shed light on its potential as a sustainable sanitation solution. However, there are several avenues for further exploration and development in this field. The future scope of this research paper lies in the following areas:

1. Technological advancements: The zero-waste toilet can benefit from ongoing technological advancements. Further research can focus on enhancing the efficiency and effectiveness of the sensor-operated system. Innovations in sensor technology, such as improved occupancy detection, water flow regulation, and waste separation mechanisms, can contribute to better performance and user experience.

2. Accessibility and afordability: To ensure widespread adoption and accessibility of zero-waste toilets, future studies should explore cost-effective approaches for manufacturing and installation. Investigating alternative construction materials and

DOI: 10.6977/IJoSI.202406_8(2).0006
P. Abhijeet, S. Sanjeev, et al./Int. J. Systematic Innovation, 8(2), 70-86 (2024)

production methods can help reduce the initial investment required for zero-waste toilets, making them more affordable for individuals and communities with limited financial resources.

3. Community engagement and user acceptance: Community engagement plays a vital role in the success of any sanitation intervention. Future research can focus on understanding the social and cultural aspects related to the acceptance and adoption of zero-waste toilets. Involving local communities, understanding their needs and preferences, and incorporating their feedback into the design and implementation process can contribute to increased acceptance and long-term sustainability.

4. Performance monitoring and evaluation: Long-term monitoring and evaluation of zero-waste toilet systems are essential to assess their performance, durability, and impact on the environment and public health. Future studies should focus on developing monitoring frameworks and evaluating the effectiveness of zero-waste toilets in terms of water savings, waste management, and resource recovery. This data can provide valuable insights for policymakers, practitioners, and researchers to optimize system performance and address any potential challenges.

5. Integration with circular economy practices: The zero-waste toilet's potential for waste-to-resource conversion opens up opportunities for integration with circular economy principles. Future research can explore ways to maximize resource recovery from human waste and integrate the by-products, such as organic fertilizers, into local agricultural practices. Understanding the socio-economic implications and assessing the environmental benefits of such integration will contribute to the overall sustainability of the zero-waste toilet system.

6. Scaling Up and Replication: While the research paper focuses on the zero-waste toilet concept, future studies can explore strategies for scaling up and replicating these systems in different contexts. Understanding the barriers and enablers for scaling up zero-waste toilet installations can help inform policy decisions and promote wider adoption of sustainable sanitation practices. Case studies and best practices from successful implementations can serve as valuable guidance for future projects.

7. Environmental impact assessment: Assessing the environmental impact of zero-waste toilets throughout their life cycle is crucial for understanding their overall sustainability. Future research should consider conducting life cycle assessments (LCAs) to evaluate the environmental footprint of zero-waste toilets, including their construction, operation, and waste management processes. This assessment will provide insights into potential areas for improvement and guide decision-making towards more environmentally friendly practices.

In conclusion, the future scope of the research paper lies in further technological advancements, cost-effectiveness, community engagement, performance monitoring, integration with circular economy practices, scaling up, and environmental impact assessment. By exploring these areas, researchers can contribute to the development and sustainability of zero-waste toilets as a viable solution for improved sanitation, environmental conservation, and community well-being.

References

Angeletti, G., & Bjørseth, A. (Eds.). (2013). Organic Micropollutants in the Aquatic Environment: Proceedings of the Sixth European Symposium, Held in Lisbon, Portugal, May 22–24, 1990, Springer Science & Business Media, 13152.

Aryza, S., Pratama, S., & Ikbal, M. (2022). An Enhance System Smart Toilet Based on Recycle Green Control. Infokum, 10(02), 1156-1163.

Cordell, D., Drangert, J. O., & White, S. (2009). The story of phosphorus: global food security and food for thought. Global environmental change, 19(2), 292-305.

Crume, R. V. (Ed.). (2018). Environmental Health in the 21st Century: From Air Pollution to Zoonotic Diseases [2 volumes]. ABC-CLIO.

Garcia-Fine, S. (2015). Redesign of the Sol-Char Toilet (Doctoral dissertation, Worcester Polytechnic Institute).

Ignacio, J. J., Alvin Malenab, R., Pausta, C. M., Beltran, A., Belo, L., Tanhueco, R. M., & Orbecido,

A. (2018). Perceptions and attitudes toward eco-toilet systems in rural areas: A case study in the Philippines. Sustainability, 10(2), 521.

Prüss-Ustün, A., Bartram, J., Clasen, T., Colford Jr, J. M., Cumming, O., Curtis, V., & Cairncross, S. (2014). Burden of disease from inadequate water, sanitation and hygiene in low-and middle-income settings: a retrospective analysis of data from 145 countries. Tropical Medicine & International Health, 19(8), 894-905.

Shafiee, S., & Topal, E. (2009). When will fossil fuel reserves be diminished? Energy policy, 37(1), 181-189.

Shah, A., Karmiani, D., Mehta, D., & Kulkarni, S. (2020, September). Solar Powered Self-Cleaning Toilet. In International Conference on Business Management, Innovation & Sustainability (ICBMIS).

Simha, P., & Ganesapillai, M. (2017). Ecological Sanitation and nutrient recovery from human urine: How far have we come? A review. Sustainable Environment Research, 27(3), 107-116.

Tilley, E., Ulrich, L., Lüthi, C., Reymond, P., & Zurbrügg, C. (2014). Compendium of sanitation systems and technologies.

United Nations Children's Fund (UNICEF) and World Health Organization (WHO). (2019). Progress on household drinking water, sanitation, and hygiene 2000-2017: Special focus on inequalities. UNICEF and WHO.

Wilderer, P. A., & Schreff, D. (2000). Decentralized and centralized wastewater management: a challenge for technology developers. Water Science and Technology, 41(1), 1-8.

AUTHOR BIOGRAPHIES

Mr. Abhijeet Patil is currently pursuing his Doctoral Programme in Research Scholar in Visvesvaraya Technological University, Belagavi-590018, Karnataka, India, He holds an M. Tech. from rajarambapu Institute of Technology, Rajaramnagar. His field of specialization is Rural Sanitation Structures. He has published 2 articles in reputed peer-reviewed National and International Journals and 2 in Edited Books. He has attended/presented the research papers in various Seminars, Conferences and Workshop at National and International level.

Dr. Sanjeev Sangami is presently working as Research Supervisor in Visvesvaraya Technological University, Belagavi-590018, Karnataka, India. He holds Doctorate from National Institute of Technology Karnataka, India. He has published 18 articles in reputed peer-reviewed National and International Journals and 2 chapters in Edited Books. He has attended/presented the research papers in various Seminars, Conferences and Workshop at National and International level. He has also organized various Seminar and Workshop at National and International level. He has made significant contributions to research in the field of Transportation Engineering and Construction Management.

Dr. Chandak P. G. is presently working as Research Supervisor in Visvesvaraya Technological University, Belagavi-590018, Karnataka, India. He holds Doctorate from Visvesvaraya Technological University, Belagavi-590018, Karnataka, India. He has published 24 articles in reputed peer-reviewed National and International Journals and 4 chapters in Edited Books. He has attended/presented the research papers in various Seminars, Conferences and Workshop at National and International level. He has also organized various Seminar and Workshop at National and International level. He has made significant contributions to research in the field of Transportation Engineering and Construction Management.

DOI: 10.6977/IJoSI.202406_8(2).0007
K.A. Hernández / J. Systematic Innovation, 8(2), 87-94 (2024)

Prostate cancer prediction using machine learning techniques

Kevin A. Hernández
Research group Automatization and artificial intelligence, Cientek Research Center, Risaralda, Colombia
Corresponding author E-mail: kevin.hernandez.gomez@outlook.com
(Received 10 January 2024; Final version received 27 February 2024; Accepted 13 April 2024)

Abstract

Prostate cancer (PCa) is currently the most frequently diagnosed cancer in men in industrialized nations and ranks as the second leading cause of male cancer-related deaths globally, early detection is crucial. Originating in the walnut-shaped gland beneath the bladder, PCa poses a significant risk when not identified in its early stages. The diagnostic process, requiring expertise from radiologists, pathologists, and physicians, is time-consuming and introduces variability, potentially leading to delayed or incorrect diagnoses. This underscores the need for efficient and reliable diagnostic tools in addressing the escalating challenge of PCa diagnosis. This study addresses the critical challenge of PCa diagnosis by employing a comprehensive approach involving feature selection methods and model performance evaluation. Utilizing a PCa dataset from Kaggle, consisting of 100 patient observations with eight independent features and a binary diagnosis result, the study explores the nuanced nature of feature relevance in PCa classification. Comparative analyses of Principal Component Analysis (PCA) and ReliefF feature selection methods reveal the limitations of PCA's emphasis on a dominant feature, while ReliefF, incorporating a distributed set of features, demonstrates improved model accuracy and stability. The Random Forest (RF) model, selected through meticulous parameter tuning, achieves an impressive 95% accuracy by leveraging a substantial number of estimators, limited tree depth, and balanced sample splitting. The findings underscore the crucial interplay between feature selection methods and model parameters in optimizing the accuracy and reliability of PCa classification models. Given the anticipated rise in PCa incidence, this research contributes valuable insights for enhancing diagnostic efficiency and addressing the challenges posed by traditional diagnostic procedures.
Keywords: Prostate Cancer, Machine Learning, Feature selection.

1. Introduction

At present, prostate cancer (PCa) stands as the most commonly diagnosed malignancy among men in highly industrialized nations and ranks as the second primary cause of male cancer-related fatalities globally. As the population continues to expand and age, it is anticipated that the global incidence of PCa will rise, reaching nearly 2.4 million new cases annually by the year 2040 (De Vos et al., 2023). PCa originates in the compact, walnut-shaped gland located beneath the bladder and in front of the rectum. When not identified in its early stages, PCa can pose a considerable risk, leading to a notable fatality rate. According to a 20-year actuarial cumulative estimate, the likelihood of death from prostate cancer is significant (ACS, 2023). Furthermore, the clinical procedures for diagnosing prostate cancer (PCa) necessitate considerable time and expertise from radiologists, pathologists, and physicians. They meticulously assess and assign a grade or stage before considering treatment options based on factors such as the cancer stage, severity, and other relevant considerations. Unfortunately, the routine diagnostic process relies on human intervention, introducing variability in outcomes that may result in delayed or incorrect diagnoses (Gravade et al., 2023).

Additionally, the diagnosis of PCa continues to be challenging because each cascade element is not fully replicated in the metastasis of prostate cancer. Traditional methods such as the digital rectal test (DRE), prostate-specific antigen (PSA) blood test, and ultrasonography are employed for PCa detection. However, these methods exhibit low sensitivity and specificity, falling short of meeting medical standards (Naeem et al., 2023).

On the other hand, machine learning (ML) algorithms have proven effective in identifying gene biomarkers associated with PCa. Researchers are drawn to this technology because of its ability to uncover hidden patterns in the data and extract relationships between features using a set of mathematical rules and statistical assumptions (Chen et al., 2022).

In this paper we present a methodology for the PCa diagnosis system based on ML classifier, the aim of this study is to use and compare various supervised machine learning algorithms like Multilayer Perceptron (MLP), Support Vector Machines (SVM), K-Nearest Neighbor (KNN), Decision Tree (DT), Naïve Bayes (NB) and Random Forest (RF). The remaining sections of the paper are organized as follows: Section 2 introduces the related works in literature. In Section 3, the materials and methods are presented. Section 4 discusses the experimental results and findings. Finally, Section 4 provides the conclusion for the paper.

2. Literature review

The examination of ML algorithms in the context of predicting PCa represents a central theme in current medical research. With a primary objective of improving the survival rates of individuals diagnosed with PCa, the development of robust prediction models holds paramount importance, for example in (Molla et al., 2023) the exploration is undertaken by utilizing a variety of ML techniques, namely SVM, KNN, NB, RF, and Logistic Regression (LR) algorithms. The objective is to predict PCa outcomes with greater precision. Notably, among the diverse ML techniques investigated, LR emerges as particularly promising, showcasing a noteworthy 86.21% accuracy in prediction results. These findings underscore the potential applicability of LR as a reliable tool for PCa prediction.

On the other hand, in (Laabidi, & Aissaoui, 2020) they specific focus on the study involves predicting diabetes and PCa, utilizing eight distinct machine learning architectures. The experiments conducted reveal promising results, with an overall accuracy of 81.3% for PCa diagnosis. Notably, the Recurrent Neural Network (RNN) emerged as the top-performing model, showcasing superior accuracy compared to other architectures. However, LR demonstrated noteworthy results, particularly when applied to scaled features.

Moreover, the methodology built in (Araujo et al., 2023) upon a comprehensive analysis of various clinical variables extracted from patients' medical records, including age, race, diabetes mellitus, alcoholism, smoking, systemic arterial hypertension, digital rectal examination, and total prostate-specific antigen levels. To validate the efficacy of the method, machine learning algorithms such as SVM, NB, KNN, DT, and MLP were employed. These algorithms were utilized to predict the likelihood of PCa presence or absence based on the gathered clinical data. The evaluation of the method's performance employed an accuracy metric, with the Linear SVM model exhibiting the highest accuracy at 86.8%.

3. Materials and methods

In this section, we present a thorough overview of the methodology utilized, feature selection techniques, covering machine learning algorithms, and a detailed description of the dataset.

3.1. Feature selection methods

Principal Component Analysis (PCA): It is a procedure leveraging statistical methods to derive features from a dataset. This involves determining the eigenvalues of various features within the dataset and projecting them into a lower-dimensional space. The derived features are commonly known as principal components. Despite being sensitive to missing or outlier values, PCA aims to preserve minimal dimensionality while retaining valuable or essential information (Alhanaya et al., 2023).

ReliefF: The fundamental concept behind the Relief algorithm is to assess features by their effectiveness in distinguishing instances that are in close proximity to each other. For every selected instance, the algorithm identifies its two nearest neighbors: one belonging to the same class, termed the nearest hit, and the other from a different class, referred to as the nearest miss. This algorithm assigns higher weights to features that effectively differentiate instances from diverse classes. Similarly, the ReliefF algorithm is developed on the same underlying rationale (Yong & Gao, 2023).

3.2. Machine learning algorithms

Multilayer Perceptron (MLP): It is a soft computing tools for constructing reliable models to address diverse and intricate engineering problems, mimicking the structure of biological neural networks. The architecture mainly consists of three components: an input layer containing features, hidden layers with synapses, a summing point, and an activation function, and an output layer displaying results. This network configuration is commonly referred to as MLP, employing multiple perceptron's or neural network units to compute specific input data. Each layer, depending on the input elements from preceding layers, features a definite number of nodes or neurons interconnected by synapses or weights converging at the summation point, resulting in a modified signal post-multiplication by varying weights. The summation point combines input signals linearly, potentially yielding a substantial output amplitude. To constrain the signal amplitude from the summation point, an activation function is employed (Deka et al., 2023).

Support Vector Machines (SVM): Is a supervised learning algorithm suitable for classification and regression. In a classification scenario, it separates labeled training data into positive and negative classes within an n-dimensional space. The SVM's objective is to identify a hyperplane that maximizes the distance between the plane and the nearest data points, known as the maximal margin hyperplane. The hyperplane's parameters, such as the n-dimensional weight vector and bias value, are determined during the learning phase. If the data are not linearly separable, the algorithm allows for some misclassification using slack variables and an error penalty parameter. The optimal hyperplane is defined by solving a convex quadratic optimization problem. In a visual representation, support vectors represent the nearest data points to the hyperplane, and the distance between them constitutes the margin. This approach is effective in addressing diverse classification challenges in engineering problems (Araste et al., 2023).

K-Nearest Neighbor (KNN): a supervised learning method addressing grouping problems, stands out as one of the most commonly employed classification algorithms in literature. Its classification process relies on known class data, making it an example-based algorithm learning from the training set. Despite its simplicity, KNN consistently delivers competitive results and can even outperform more complex learning algorithms in certain cases, especially when dealing with a smaller number of classes. This method proves to be a simpler yet effective machine learning approach, particularly in situations with multiple categorized data points. KNN finds applicability not only in classification but also in solving regression problems, especially when independent variables are quantitative, and the classification process depends on the distances between observations. Although possessing a straightforward structure, KNN does entail a high computational cost (Erdem & Bozkurt., 2021).

Decision Tree (DT): Is a formalism used to express mappings, comprising tests or attribute nodes connected to two or more subtrees and leaf nodes. Decision nodes or leaf nodes are labeled with a class, representing the decision. A test node calculates an outcome based on the attribute values of an instance, with each possible outcome associated with one of the subtrees. Classification of an instance involves starting at the root node of the tree. If this node is a test, the outcome for the instance is determined, and the process continues using the appropriate subtree. When a leaf is encountered, its label provides the predicted class for the instance (Podgorelec, 2002).

Naïve Bayes (NB): Serves as a straightforward probability classifier, determining probabilities by tallying the frequency and combinations of values within a given dataset. Employing Bayes's theorem, the algorithm operates under the assumption of independence among all variables, given the class variable. While this conditional independence assumption may be deemed "naive" and is rarely valid in real-world applications, the algorithm demonstrates a rapid learning capability across diverse controlled classification problems. Bayes's theorem, a mathematical formula named after the 18th-century British mathematician Thomas Bayes, is utilized to calculate conditional probability (Saritas & Yasar, 2019).

Radom Forests (RF): Is a combination of classifiers where each classifier contributes a single vote for assigning the most frequent class to the input vector. The majority vote in RF representing the class prediction of the random forest tree. The amalgamation of many classifiers gives RF distinct characteristics, setting it apart from traditional DT. Therefore, RF should be perceived as a novel concept in classifiers. RF enhances tree diversity by growing them from different training data subsets, which are created through bagging or bootstrap aggregating. Bootstrap aggregating involves randomly resampling the original dataset with replacement, thus generating subsets with varied data. RF serves as an ensemble classification algorithm that utilizes trees as base classifiers (Rodriguez-Galiano., et al 2012).

3.3. Dataset description

To assess the performance of the methods evaluated in this study, a prostate cancer dataset was employed in the initial phase of the design flow. The dataset, accessible through the Kaggle platform (Sajid, 2018),

DOI: 10.6977/IJoSI.202406_8(2).0007
K.A. Hernández / J. Systematic Innovation, 8(2), 87-94 (2024)

comprises observations from 100 patients (62 records for PCa patients and 38 records for non-PCa patients). It includes eight independent features (radius, texture, area, perimeter, compactness, smoothness, fractal dimension, symmetry) and one dependent variable (diagnosis result). The label is represented by the diagnosis results, categorized by two values "B" for benign tumors and "M" for malignant tumors. The detailed information about the data is presented in Table 1

Table 1. Prostate cancer dataset feature descriptions.

Feature	Description
Radius	Refers to the average distance from the center to the perimeter of the cancer cell. This feature is often used to characterize the size of the cell.
Texture	Describes the variation in gray-scale intensity of the cancer cell, providing information about the homogeneity of the cell's internal structure.
Perimeter	Represents the total length of the boundary of the cancer cell, offering insights into the shape and contour.
Area	Denotes the total area covered by the cancer cell, contributing to the overall size assessment.
Smoothness	Describes the local variation in radius lengths, giving an indication of how smooth or irregular the cancer cell surface is.
Compactness	Reflects the compactness of the cancer cell shape, derived from the ratio of perimeter^2 to area.
Symmetry	Represents the symmetry of the cancer cell shape, providing information about its regularity.
Fractal dimension	Describes the complexity of the cancer cell shape at different scales, offering insights into the irregularity and intricacy of the cell structure.

4. Results and discussion

In this section, we unveil the outcomes derived from the applied methodology. We start with the results of the feature and model selection stage; wherein numerous experiments were conducted by training each model under different feature selection configurations (None, PCA and ReliefF). The optimal model from this stage was then chosen for subsequent parameter tuning.

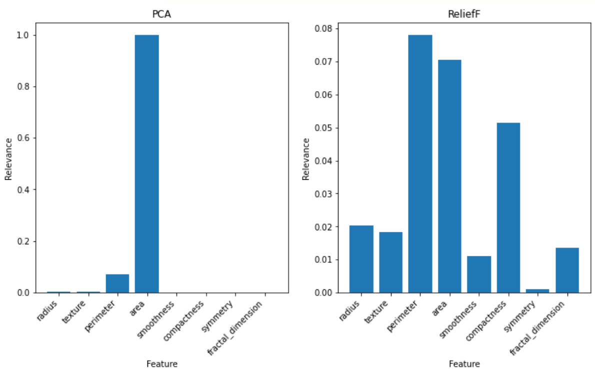


Figure 1. Feature relevance, PCA method (left) and ReliefF (right).

For the PCA method, the feature relevance score for "area" is the highest, close to 1.0, while the other features have near to zero scores. This suggests that "area" is the dominant feature that explains most of the variance in the data, and the other features are redundant or irrelevant. However, this does not mean that "area" is the best feature for classification or regression, as it may not capture the differences between the classes.

In the other way, the ReliefF method, the feature relevance scores are more distributed among the features. The feature "perimeter" has the highest score, but it is much lower than in the PCA method. This indicates that "perimeter" is still a relevant feature for classification, but it is not the only one. Other features, such as "area" and "compactness", also have notable scores, which means that they are also useful for distinguishing between the classes. The remaining features have relatively low relevance scores, which means that they are less important or redundant.

DOI: 10.6977/IJoSI.202406_8(2).0007
K.A. Hernández / J. Systematic Innovation, 8(2), 87-94 (2024)

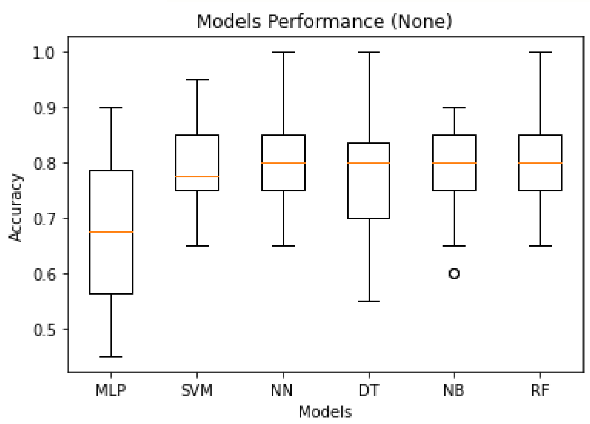


Figure 2. Models' performance for None feature selection.

The figure reveals that among the models, MLP has the widest range of accuracy (0.68±0.11), which suggests that it is unstable and sensitive to the data. SVM, DT and NB have more consistent accuracy, but they are still below 0.8, 0.79±0.08, 0.76±0.1 and 0.78±0.08 respectively. NN, and RF have similar median accuracy and variability, 0.81±0.08 and 0.82±0.08 respectively. These results imply that as some features may be irrelevant or redundant for the classification task.

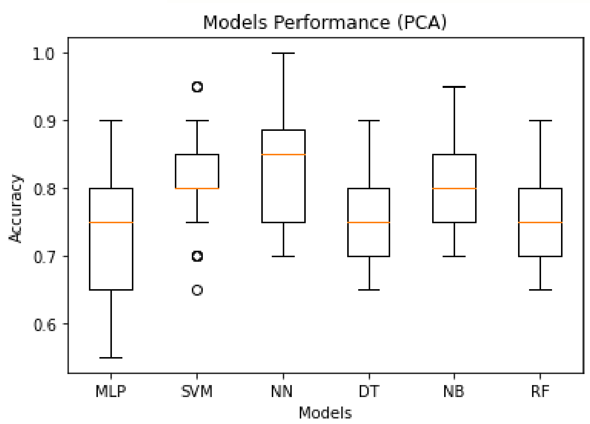


Figure 3. Models' performance for PCA feature selection.

The figure shows the PCA feature selection based on the "area" as unique feature. Equal to none feature selection, MLP has the widest range of accuracy (0.74±0.09), similar to DT and RF with 0.76±0.07 each. NN has the highest median accuracy 0.83±0.07 near are SVM and NB with 0.82±0.07 each. This implies that PCA feature selection may not be the best choice for this classification task, as it only considers the "area" feature and ignores the other features that may be relevant or informative.

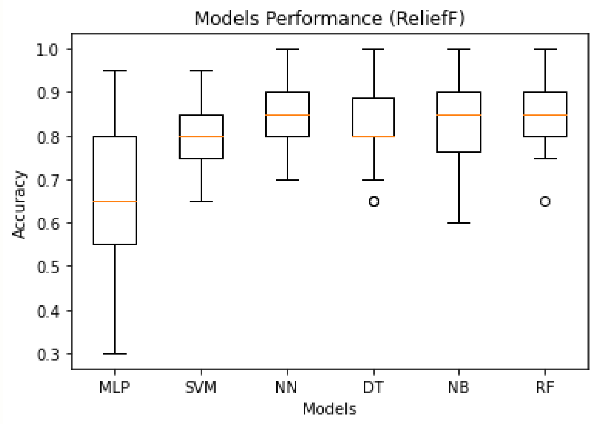


Figure 4. Models' performance for ReliefF feature selection.

DOI: 10.6977/IJoSI.202406_8(2).0007
K.A. Hernández / J. Systematic Innovation, 8(2), 87-94 (2024)

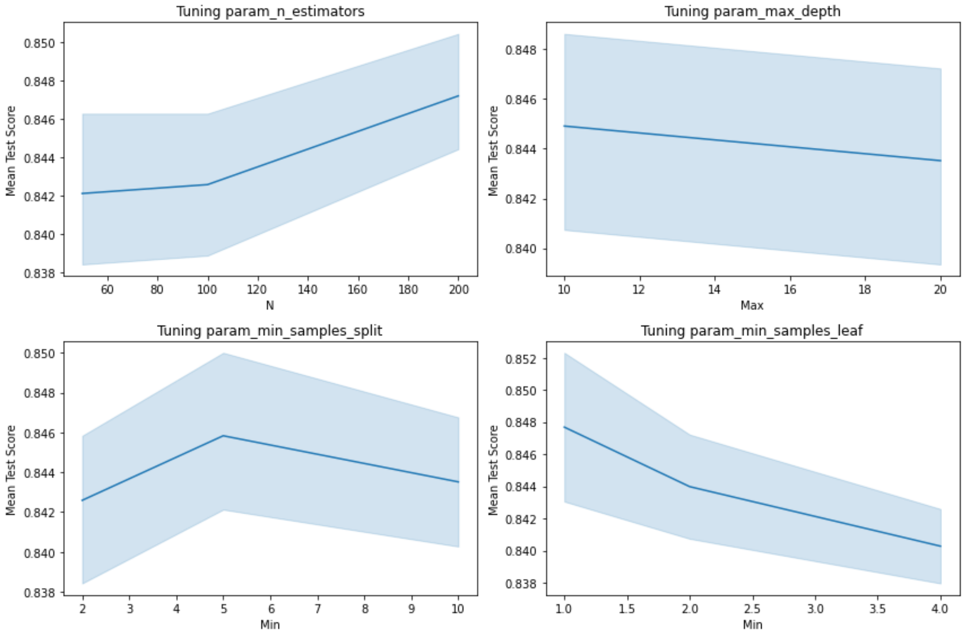


Figure 5. RF parameter tunning values.

ReliefF feature selection is based on three features: “perimeter,” “area,” and “compactness”. Here the results improve for four of the six models (NN, DT, NB, and RF) with 0.84±0.07, 0.82±0.08, 0.83±0.08 and **0.85±0.08** respectively, being RF the best model in all experiments, while MLP and SVM give lower scores 0.65±0.15 and 0.81±0.08. This implies that ReliefF feature selection may be beneficial for improving the accuracy and stability of the models, as it considers the “perimeter”, “area” and “compactness” that are relevant and good predictors for prostate cancer classification tasks.

Finally, we opted for the RF model during the parameter tuning phase. For this stage, we employed a parameter grid encompassing "number of estimators" (50, 100, 200), "max depth" (None, 10, 20), "minimum samples split" (2, 5, 10), and "minimum samples leaf" (1, 2, 4). The optimal model was determined to have the following parameter values: 200 for the number of estimators, 10 for max depth, 5 for minimum samples split, and 1 for minimum samples leaf (**Figure 5**). This refined model achieved an impressive accuracy score of 95% for diagnosing PCa.

The noteworthy accuracy of this model can be attributed to the combination of a substantial number of estimators (200), an appropriately limited tree depth (10), and a balanced approach to splitting samples. The minimal leaf samples (1) further contribute to the model's precision, ensuring that each leaf node captures a sufficient amount of information without overfitting the data. This comprehensive parameter selection enables the Random Forest model to robustly discern patterns in the dataset, leading to its high accuracy in PCa diagnosis.

5. Conclusion

In conclusion, the comparative analysis of feature selection methods and subsequent model performance evaluation highlights the nuanced nature of feature relevance in PCa classification. PCA, with its emphasis on the dominant "area" feature, may oversimplify the task by neglecting other informative features, potentially compromising classification accuracy. In contrast, ReliefF, incorporating "perimeter," "area," and "compactness," demonstrates improved model accuracy and stability, emphasizing the significance of a more distributed feature selection approach. The RF model, chosen through parameter tuning, achieves an impressive 95% accuracy by effectively leveraging a substantial number of estimators, limited tree depth, and balanced sample splitting. This underscores the importance of a meticulous parameter selection process, contributing to the model's robust ability to discern meaningful patterns in the PCa dataset. Overall, the study underscores the critical interplay between feature selection methods and model parameters in optimizing the accuracy and reliability of PCa classification models.

References

ACS (American Cancer Society). (2023). Survival Rates for Prostate Cancer. Atlanta, GA, USA.

Alhanaya, M., & Ateyeh Al-Shqeerat, K. H. (2023). Performance Analysis of Intrusion Detection System in the IoT Environment Using Feature Selection Technique. Intelligent Automation & Soft Computing, 36(3).

Araste, Z., Sadighi, A., & Jamimoghaddam, M. (2023). Fault diagnosis of a centrifugal pump using electrical signature analysis and support vector machine. Journal of Vibration Engineering & Technologies, 11(5), 2057-2067.

Araujo, W. B., Santana, E. E., Sousa, N. P., Junior, C. M., Allan Filho, K. D. B., Moura, G. L., ... & Silva, F. C. (2023). Method to aid the diagnosis of prostate cancer using machine learning and clinical data.

Chen, S., Jian, T., Chi, C., Liang, Y., Liang, X., Yu, Y., ... & Lu, J. (2022). Machine learning-based models enhance the prediction of prostate cancer. Frontiers in Oncology, 12, 941349.

De Vos, I. I., Luiting, H. B., & Roobol, M. J. (2023). Active Surveillance for Prostate Cancer: Past, Current, and Future Trends. Journal of Personalized Medicine, 13(4), 629.

Deka, M. J., Kalita, P., Das, D., Kamble, A. D., Bora, B. J., Sharma, P., & Medhi, B. J. (2023). An approach towards building robust neural networks models using multilayer perceptron through experimentation on different photovoltaic thermal systems. Energy Conversion and Management, 292, 117395.

Erdem, E., & Bozkurt, F. (2021). A comparison of various supervised machine learning techniques for prostate cancer prediction. Avrupa Bilim ve Teknoloji Dergisi, (21), 610-620.

Gavade, A. B., Nerli, R., Kanwal, N., Gavade, P. A., Pol, S. S., & Rizvi, S. T. H. (2023). Automated diagnosis of prostate cancer using mpmri images: A deep learning approach for clinical decision support. Computers, 12(8), 152.

Laabidi, A., & Aissaoui, M. (2020, April). Performance analysis of Machine learning classifiers for predicting diabetes and prostate cancer. In 2020 1st international conference on innovative research in applied science, engineering and technology (IRASET) (pp. 1-6). IEEE.

Molla, M. I., Jui, J. J., Rana, H. K., & Podder, N. K. (2023, January). Machine Learning Algorithms for the Prediction of Prostate Cancer. In Proceedings of International Conference on Information and Communication Technology for Development: ICICTD 2022 (pp. 471-482). Singapore: Springer Nature Singapore.

Naeem, A., Khan, A. H., u din Ayubi, S., & Malik, H. (2023). Predicting the Metastasis Ability of Prostate Cancer using Machine Learning Classifiers. Journal of Computing & Biomedical Informatics, 4(02), 1-7.

Podgorelec, V., Kokol, P., Stiglic, B., & Rozman, I. (2002). Decision trees: an overview and their use in medicine. Journal of medical systems, 26, 445-463.

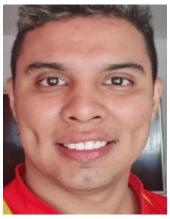
Rodriguez-Galiano, V. F., Ghimire, B., Rogan, J., Chica-Olmo, M., & Rigol-Sanchez, J. P. (2012). An assessment of the effectiveness of a random forest classifier for land-cover classification. ISPRS journal of photogrammetry and remote sensing, 67, 93-104.

Sajid S. (2018). Prostate cancer dataset, [Online]. Available: https://www.kaggle .com/sajid-saifi/prostate cancer

Saritas, M. M., & Yasar, A. (2019). Performance analysis of ANN and Naive Bayes classification algorithm for data classification. International journal of intelligent systems and applications in engineering, 7(2), 88-91.

Yong, X., & Gao, Y. L. (2023). Improved firefly algorithm for feature selection with the ReliefF-based initialization and the weighted voting mechanism. Neural Computing and Applications, 35(1), 275-301

AUTHOR BIOGRAPHY



Kevin A. Hernández has been a Researcher at Cientek Research Center in Colombia since 2023. Kevin graduated from physics engineering and his master's degree in electrical engineering at Universidad Tecnologica de Pereira. He is currently aiming for his Ph.D. His areas of interests include Machine Learning and Deep Learning.

DOI: 10.6977/IJoSI.202406_8(2).0008
S. Kumar, U. Pilania, et al./ Int. J. Systematic Innovation, 8(2), 95-112 (2024)

A novel hybrid deep belief Google network framework for brain tumor classification

Sanjeet Kumar[1]*, Urmila Pilania[1], Rajni Bala[2]
[1]Department of Computer Science and Technology
Manav Rachna University
Faridabad, Haryana-121004, India
[2]Department of Computer Science
Deen Dayal Upadhyaya College, University of Delhi
Sector-3, Dwarka, New Delhi-110078, India
*Corresponding author E- mail: sanjuonline1@gmail.com
(Received 23 January 2024; Final version received 27 March 2024; Accepted 15 April 2024)

Abstract

A brain tumor can lead to headaches, seizures, numbness or weakness in the arms or legs, changes in personality or behavior, nausea, vomiting, visual or hearing disturbances, or dizziness. Brain tumors are lumps or atypical expansions of cells that develop in the brain or central spinal canal. The current study used neural networks to identify with categorize brain tumors, although it has the drawbacks of longer delays in processing, overfitting, and exploding gradient. This study proposed a unique Hybrid Deep Belief Google Network (DBGN) system for brain tumor identification and categorization in order to get over the constraints. Pre-processing and feature extraction with categorization are the components of this method. Utilizing the proposed Modified Global Contrast Stretching (MGCS), Hybrid Median and Wiener Filter (HMWF), and Modified Scharr operator to first pre-process the obtained pictures. Next, a fresh, efficient neural network was proposed by this study to gather and classify the brain tumor. As a result, the method we propose outperforms the existing approaches in relation to accuracy, precision, recall, and specificity.

Keywords: Brain tumor, Medical imaging, Magnetic Resonance Imaging (MRI), tumor classification, deep learning, neural network.

1. Introduction

An arrangement of uncommon or unusual cells that have developed inside the brain is referred to as a brain tumor (Gore et al 2020). The brain's hard outer shell, the skull, serves as a protective barrier in case of injury. A major issue will arise if there is any erratic cell proliferation within it (Fernandes et al 2020 & Khan et al. 2019). Brain tumors come in two different varieties: benign, which may be cured if discovered in advance, & malignant, which can be more serious and challenging to cure Razzaq et al. 2020 & Sharif et al. 2020). Additionally, around 70% of individuals suffer from primary or metastatic brain tumors, often known as gliomas, which are the supreme prevalent kinds of brain tumors that rise from glial cells. The classifications of low-grade (oligodendroglia) with high-grade (glioblastoma) tumor cells both exhibit proliferative behavior (Amin et al. 2020). When a tumor is diagnosed early in the course of the illness, it becomes less dangerous than when it is found later on, when the patient's life expectancy is reduced to a minimum of two years. Chemotherapy, ionizing radiation surgery, or a combination of these is the finest and greatest efficient treatment for cancer patients. Over a million people are diagnosed with a brain tumor every year, also the mortality rate associated with these malignancies is growing quickly, according to Global Cancer Research. In young people and kids below the age of 34, it ranks as the second-highest rate of mortality (Majib et al. 2021 & Sravan et al.2020).

A unique meta-heuristic and ML-based technique is offered in the current study, which is mentioned below, for an early identification of brain cancer to overcome this objection: A Support Vector Machine (SVM)-based tumor identification technique has been suggested (Kabir 2020). When the data set has additional noise, SVM fails to operate as well. The researchers (Chen et al. 2021) created an Extended Kalman Filter with

Support Vector Machine (EKF-SVM), an image processing framework reliant on an SVM, for automated brain tumor identification. The Kalman Filter, is not the best estimator. Additionally, a powerful system for classifying MRI brain images is offered by Mishra et al.2021). For feature extraction and coefficient selection, it uses a variety of wavelet transformations, such as the Discrete Wavelet Transform, Stationary Wavelet Transform, and Dual-tree M-band Wavelet Transform. Although shift sensitivity, weak directionality, with an absence of phase knowledge are drawbacks of the wavelet transform.

In order to categorize the tumor grades, the researchers (Sharif et al. 2020) used an Artificial Neural Network (ANN), where these skulls were extracted utilizing the Brain Surface Extraction (BSE) procedure. To improve segmentation, a picture with the skull eliminated is subsequently sent into PSO. The best choice of characteristics with classification phases is then made using a revised version of the Whale Optimization Algorithm (WOA) that utilizes chaos concept with the logistic mapping approach (Yin et al. 2020). The WOA's shortcoming is that it converges slowly, and accurately, and is prone to a local optimum. Hence, ML-based approaches are time-consuming, and more resources are required and inaccuracy of the interpretation of data, to overcome that, DL-based techniques are proposed to identify & categorize brain tumors:

By using a DNN framework, the researchers (Acharya et al. 2020) aimed to enhance the present best practice model. To improve the precision of segmentation and feature-extraction stages with the subsequent segmentation, this necessitated altering those stages. Additionally, by utilizing swarm intelligence-based techniques like GA, PSO, GWO, and WOA, researchers (Mishra et al.2021 & Irmak 2021) provided a structure for optimizing network settings including the weight and bias vector of DCNN networks. The location and orientation of objects were not properly encoded by the DCNN. Additionally, the researchers (Kujur et al.2022 & Togacar et al. 2021) compare the classification performance of significant research on four CNN forms including CNN trained from scratch, ResNet50, InceptionV3, and Xception, over two brain MRI datasets of pictures analyzed with and without the use of Principal Component Analysis.

A brand-new residual network framework that utilizes multi-scale feature fusion with global average pooling (GPA) has been suggested by researchers (Li et al. 2022 & Jun et al.2022). Still, average pooling entails figuring out the average for every feature map patch. In order to address this, the researchers (Masood et al. 2021) proposed a custom Mask Region-based Convolution Neural Network with a dense net-41 backbone structure that is trained using transfer learning for precise segmentation as well as classification of brain tumors. It works on still images, so cannot explore temporal information of the object of interest. Moreover, the authors (Kumar et al. 2023) made a systematic review of recent deep learning, machine learning, and hybrid models for detecting brain cancers. Thus, this study presented a hybrid deep neural network for brain tumor identification and categorization to get beyond the aforementioned constraints. This study's primary contribution is as listed below:

- The study addresses the common symptoms associated with brain tumors, such as headaches, seizures, numbness, changes in personality, and visual disturbances. It emphasizes the importance of accurately identifying and categorizing these tumors for effective treatment.
- The study utilizes neural networks for brain tumor identification, acknowledging existing drawbacks such as longer processing delays, overfitting, and issues with exploding gradients. This highlights the relevance of advancing neural network techniques to overcome these limitations.
- The proposal of a Hybrid DBGN system, which integrates various pre-processing techniques like MGCS, HMWF, and Modified Scharr operator. These techniques aim to enhance image quality and facilitate more accurate tumor classificaton.
- The study incorporates feature extraction and categorization components within the Hybrid DBGN system to efficiently gather and classify brain tumors. This comprehensive approach ensures robust performance in tumor identification.

As a result, our proposed approach efficiently detects and classifies the brain tumor. The following is how this research study is organized: The overview of brain tumor identification and categorization employing neural networks in Section 2 is followed by a discussion of a novel network that was developed in this study to get beyond the current study's constraints in Section 3. Additionally, Section 4 deliberates the outcomes of this proposed strategy, and Section 5 closes this study article.

2. Literature survey

For the purpose of detecting brain tumors employing MR images, (Rammurthy et al. 2022) offered the Whale Harris Hawks optimization (WHHO) optimization-driven approach. The segments' characteristics, including the variance, the local optical orientation pattern, mean, tumor's size, and kurtosis, are also obtained. For the diagnosis of brain tumors, a deep convolutional neural network (DCNN) is also used, and its training is carried out using a recommended hybrid WHHO algorithm. Although owing to procedures like max-pooling, the deep CNN frequently runs slower. In addition, the hybrid WHHO is susceptible to local optimums and therefore has a poor convergence pace.

Utilizing a dataset from Kaggle and BRaTS MICCAI that included a broad variety of cancers, every having its dimension, position, and appearance together with varying degrees of image intensity, (Solanki et al. 2023). When performing the traditional step of categorization, an overall of six different classification algorithms, including Naive Bayes, KNN, SVM, Logistic Regression, and Multi-layer Perceptron, were applied. After that, a CNN is deployed, showing a considerable improvement in efficiency as a whole when compared to the conventional classifiers.

With a T1C modality MRI image, (Patil et al. 2023) developed a shallow CNN (SCNN) and VGG16 network, and then its precision and loss were assessed. The collected features from the two DL models were combined to increase the classification accuracy of three different tumor kinds, which improved the model's performance with regard to accuracy and information loss. The ensemble DCNN model's (EDCNN) results demonstrated that the combination of DL models increases the accuracy of the challenge of classifying multiple classes as well as tries to solve the issue of overfitting the model for unbalanced datasets.

A transfer learning-based DCNN approach was presented by (Malla et al. 2023) to categorize brain malignancies. The authors employed a pre-trained DCNN framework called VGGNetwork that was validated on a large amount of data before being applied to the target dataset. Additionally, we use transfer learning techniques like optimizing the convolutional network and freezing its parts to improve performance. Additionally, to prevent overfitting concerns and vanishing gradient challenges, for that, GAP is utilized in the output layer.

A unique Hybrid-Brain-Tumor-categorization (HBTC) construction was established by (Nawaz et al. 2022). It was introduced to the test for classifying brain tumors. Hence, the technique's effectiveness is increased while its inherent complexity is decreased. The feature vector was then subjected to a hybrid multi-features optimizing process that resulted in a completely optimized feature dataset.

(Archana et al. 2023) suggested a different process for finding brain malignancies consuming the Bagging Ensemble with KNN (BKNN) with the goal to increase the precision and quality rate of KNN. A U-Net framework is utilized originally for picture segmentation, then a Bagging-based KNN prediction method is utilized for classification. U-Net is used to increase the regularity and precision of parameter distribution in levels. Big data sets make it extremely costly to determine the distance between every new point with every old point, which lowers the technique's efficiency even while accuracy has increased. In the years to come, the accuracy of classification can be improved by employing supervised techniques like CNNs.

To identify brain cancers, (Asad et al. 2023) suggested a deep CNN using a stochastic gradient descent (SGD) optimization technique. Utilizing ResNet-50 model, the public Kaggle brain-tumor dataset is consumed to test the multi-classification of brain tumors.

A Harris Hawks Optimized Convolution Network (HHOCNN) strategy was suggested by (Kurdi et al. 2023). The MRI data gathered from Kaggle dataset, that includes both normal and pathological brain scans, is used to assess the suggested technique. The output is recognized by the totally convolute layers by adjusting the parameter in accordance with HHO algorithm. The Harris Hawks optimizing approach, which draws inspiration from nature, reduces the misclassification error rate and increases total tumor detection precision.

(Kumar et al.), suggested a conditional integration and supplementary classification of brain tumors by pretraining a Style-based Generative Adversarial Network (GAN). In order to enhance classification accuracy when the training data is limited, the discriminator of the pre-trained GAN is tweaked utilizing advanced data augmentation techniques. The scheme works properly even when there are few data points available.

(Saeedi et al, 2023)., a convolutional auto-encoder

DOI: 10.6977/IJoSI.202406_8(2).0008
S. Kumar, U. Pilania, et al./ Int. J. Systematic Innovation, 8(2), 95-112 (2024)

network, a unique 2D CNN structure, with six widely used ML methods created for brain tumor identification. A $T1$-weighted, contrast-improved MRI dataset consisting of three different kinds of cancers with a healthy brain without tumors was used for this categorization.

(Babu et al 2023)., suggested Artificial Bee Colony (ABC) Optimization to eliminate malignancies from brain MRI data in combination with thresholding. To restore the CNN's learning rate for the last hybrid classification, an additional optimization strategy is utilized. The learning rate of CNN is expanded by utilizing the butterfly optimization procedure for superior categorization. This work might be expanded in subsequent years to segment and pinpoint the location of sub-tumoral sections, i.e., for improving non-enhance and entire tumors. With an objective to increase the accuracy and Diagnostic Confidence Index (DCI) of the present study, we also want to examine an extra robust technique for a sizable archive of healthcare images with a selected classifier by combining a number of classifiers.

The following discussion addresses the disadvantages of the current methods for finding and categorizing brain tumors based on the evaluations provided above: CNN with hybrid WHHO has slower performance due to the max-pooling layer and is more prone to falling into the local optimum, which increases execution time. The VGG-16 network requires more time to train its parameters, the MLP has too many parameters because it is fully connected, which negatively affects performance. This study thus suggested a unique hybrid network for brain tumor identification and categorization to get over the aforementioned constraints.

3. The Novel framework for brain tumor classification

To get beyond the aforementioned drawbacks, this study introduced a unique Hybrid Deep Belief Google Network (DBGN) structure for brain cancer recognition and categorization. The three essential processes in this innovative architecture are pre-processing feature extraction, and classification. Image enhancement, denoising, & recognition of edges are first carried out during the pre-processing step. For image enhancement, this research proposed a MGCS, to denoise the images Hybrid Median and Wiener Filters are proposed, and to detect the edges in the images, this research proposed a modified Scharr Operator. The following phase entails the proposal of a fresh, optimal neural network for the extraction and classification of brain tumor feature information. Here, to extract the features HH-BWO-based DBN is proposed, and following that, the brain tumor is classified by using GoogLeNet auxiliary classifier. Figure 1 depicts the proposed method's design.

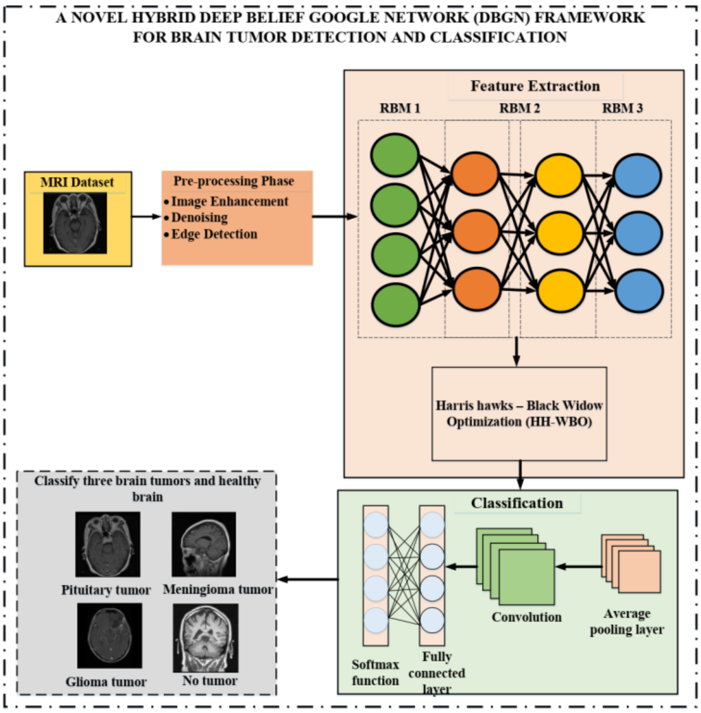


Fig 1. Architecture of the proposed approach

3.1 Dataset description

As demonstrated in **Figure 2**, the model we proposed was analyzed and evaluated using data from an open-source brain tumor dataset (Ozkaraca et al.2023). The data set has an overall four classifications, as illustrated in Figure 2. These are MRI scans of the brain taken from healthy (H), meningioma tumor (MT), pituitary tumor (PT), and glioma tumor (GT). The MRI image dataset includes 7022 files. The collection includes 405 photos of healthy people and 300 photographs each of GT, MT, PT, and H. For this investigation, 800 photos have been taken. We divided this up into 200 photos for glioma, 200 for meningioma, 200 for pituitary, and 200 for healthy people. The Kaggle program offers the dataset as open-source data. This kind of brain tumor is labeled on each 224 224 JPEG file, which is included in the collection. 80% of this dataset is used for training, while 20% is used for testing.

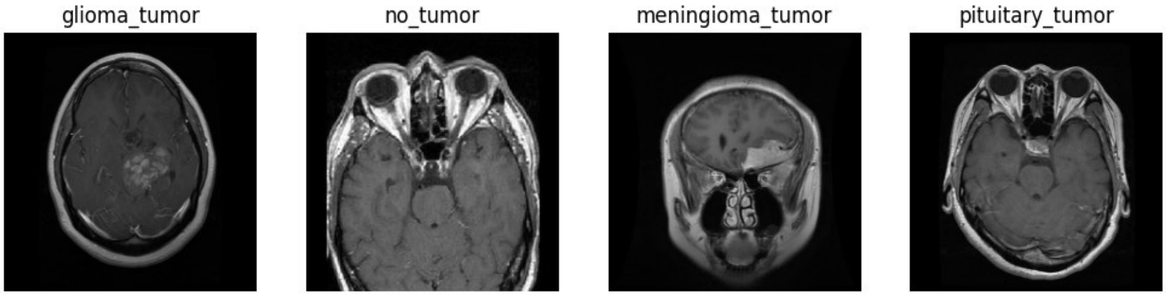


Figure 2. Classes of the dataset

3.2 Pre-processing (P-P) phase

The first phase of the proposed approach is preprocessing, where image enhancement, denoising, and edge detection are carried which is described in the following section.

3.2.1 Image enhancement

The weaknesses of obtained MRI images include blurriness and poor contrast. The contrast enhancement method is essential for enhancing the clarity and contrast of MRI images. Contrast stretching is the technique of widening the color space such that all possible values may be used to enhance a picture. It alters how many digital integers are distributed across every single pixel in a picture along with their range. As a result, the novel MGCS contrast-enhancing approach has been suggested. For every RGB (Red, Green, and Blue) component of the picture, it establishes the most recent lowest & highest values.

In order to calculate the updated lowest and highest possible values for every single of the RGB elements in the image using the MGCS technique, a number of parameters must be acquired. The lowest and highest proportions, the sum of pixels in every pixel point, overall quantity of pixels falling within a specified minimum %, and the total number of pixels falling inside a specified maximum proportion are all included in these figures. Additionally, it enhances contrast by expanding the intensity levels in an image to include a specified range of values. However, the contrast-stretching algorithm is susceptible to noise, so a hybrid median and wiener filter is proposed to effectively reduce the noise, as described below.

3.2.2 Denoising

To eliminate the noise in the enhanced images, this research offered a Hybrid Median and Wiener Filter (HMWF), here, a median filter reduces the noise, in addition, a wiener filter is used to efficiently remove the blurring. Images can be obtained by applying median and Wiener filters. The following is a description of the fundamental steps of the wiener and median filters:

The initial matrix of the spatial noise reduction filter is configured to be of size $m \times n$. For the improved image (section 3.1.1), the matrix is utilized to generate new pixels with sizes according to their values. The median filter then transforms every pixel's value into median pixel value, which is equal to center pixel assessment of the matrix. Additionally, the wiener filter utilizes both variation and average pixel values in m × n-sized matrix, as illustrated in the example below:

$$\mu = \frac{1}{MN} \sum_{m,n\epsilon\eta} a(m,n) \quad (1)$$

$$\sigma^2 = \frac{1}{MN} \sum_{m,n\epsilon\eta} a^2\,(m,n) - \mu^2 \quad (2)$$

Where MN is the image's size, μ is its mean, σ^2 is its variance from noise, m × n is the size of the η neighborhood region, and $a(m,n)$ denotes every pixel in the neighborhood η. Utilizing the estimated values, the Wiener filter is applied to new pixels, that can be expressed as $b_w(m,n)$.

$$b_w(m,n) = \mu + \frac{\sigma^2 - v^2}{\sigma^2}.(a(m,n) - \mu) \quad (3)$$

Where v2 is the matrix's noise variance setting used in the Wiener filter implementation. Regardless of the noise level, the wiener filter reduces the mean square error. To overcome the limitations, this research proposed a hybrid median and wiener filter (HMWF) which is described as follows: Applying the median filter to the backdrop of deteriorated photos, this approach enhances the image quality. Additionally, this HMWF uses the wiener filter to mostly maintain the edge signal. The HMWF approach, which relies on the wiener filter, reduces noise in the deteriorated image by replacing the matrix's pixel values with median values.

The median value ($\tilde{\mu}$) is used in place of the average value (μ) in the wiener filter equation. The following is a representation of the HMWF:

$$b_{HMWF}(\mathrm{m,n}) = \tilde{\mu} + \frac{\sigma^2 - v^2}{\sigma^2}.(a(m,n) - \tilde{\mu}) \quad (4)$$

The proposed HMWF technique removes the background noise signal. Because of this, the HMWF approach can significantly outperform traditional filters in terms of denoising impact. However, the edges of the images are not preserved by the proposed HMWF technique, to overcome the limitations this research proposed a Modified Scharr Operator which is described as follows:

3.2.3 Edge detection

To preserve the edges of MRI images, this research proposed a Modified Scharr Operator, here, we utilize the Laplacian method, and an image's Laplacian indicates areas where the intensity changes quickly. The MRI image's X and Y directions are first evaluated using the Scharr operator, and then the images are sharpened using either a positive or negative Laplacian operator.

Utilizing the Scharr operator, the initial derivative can be utilized to identify and highlight gradient edges or features in a picture. The x and y axes such as (dx = 1, dy = 0; dx = 0, dy = 1) are the two axes that are frequently used to determine gradients. It increases the variance among the pixel values by amplifying the weight coefficient. However, the Scharr derivative cannot be computed for both X and Y directions simultaneously. Therefore, we apply a positive or negative Laplacian operator on the derived results of the Scharr operator. We have a conventional image in Positive Laplacian, where the corner components of the picture must be zero and the center element of the picture must be negatives. We have a typical picture in the negative Laplacian operator, where the center element ought to be positive. The remainder of the components in the mask ought to be -1, while each of the elements in the corner must be set to zero. The sharpened picture is then obtained by subtracting the outcome from the original picture.

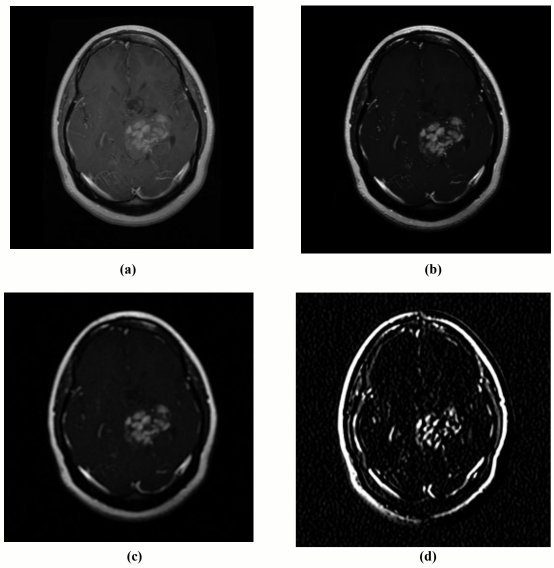


Figure 3. Pre-processed result (a) original image (b) MGCS (c) HMWF (d) Scharr Operator

DOI: 10.6977/IJoSI.202406_8(2).0008
S. Kumar, U. Pilania, et al./ Int. J. Systematic Innovation, 8(2), 95-112 (2024)

The pre-processing step of this research improved the MRI images by removing noise and maintaining image edges, which increased the accuracy for identifying and classifying brain tumors.

3.3 The novel optimized neural network proposed

The unique optimal neural network developed for brain cancer feature extraction and categorization is then fed the preprocessed pictures. Here, Deep Belief Network (DBN) is proposed to remove the features in the dataset such as color, and shape features. Moreover, to fine-tune the hyperparameters in the DBN network, this research proposed a Harris hawk – Black Widow Optimization (HH-BWO) that is explained in the part below.

3.3.1 Optimization-based feature extraction

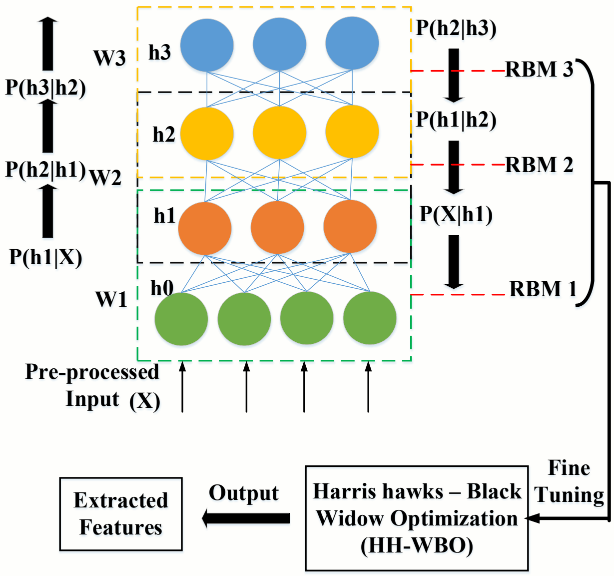


Figure 4. Architecture of Optimized Deep Belief Network.

A stacked Restricted Boltzmann Machine (RBM) and Sigmoid belief network make up the DBN, a generative model of the DNN (see Figure 3). Three stacked RBMs with three hidden layers—$\{hid^1, hid^2, hid^3\}$—can be found in the provided DBN. The procreative stochastic ANN, represented by the RBM1 in Figure 4, is created by connecting the input vector $\{inp\ X = hid^0\}$ and the hidden layer h^1.

The RBM1 was trained using the constructive divergence method because DBN only takes into account one stratum for first- stratum training. To freeze the weight W1 for second-stratum training, the upper stratum of DBN is treated as RBM 2, and lower stratum is treated as a sigmoid belief network. Similar to second- stratum training, 3rd stratum training considers the top stratum to be RBM-3 and the other two to be sigmoid belief networks, freezing weights W1 and W2. Equation (5) presents mathematical representation of the DBN.

$$P(inp\ X, hid^1, hid^2, \ldots hid^n) = P(inp\ X|\ hid^1)\ P(hid^1|hid^2) \ldots P\left(hid^{(n-2)}\middle|\ hid^{(n-1)}\right) P\left(hid^{(n-1)}\middle|hid^n\right) \quad (5)$$

The probability $P(hid^{(n-1)}, hid^n)$ of (1) is determined through RBM using (6) and (7).

$$P\left(hid^i\middle|\ hid^{(i+1)}\right) = \prod_j P\left(hid_j^i\middle|hid^{(i+1)}\right) \quad (6)$$

$$P\left(hid_j^i\middle|hid^{(i+1)}\right) = \sigma\left(b_j^i + \sum_K^{i+1} W_{kj}^i\ hid_k^{i+1}\right) \quad (7)$$

DOI: 10.6977/IJoSI.202406_8(2).0008
S. Kumar, U. Pilania, et al./ Int. J. Systematic Innovation, 8(2), 95-112 (2024)

The RBM has the ability to create characteristics & rebuild inputs. Then, this research presented a Harris Hawks - Black Widow Optimisation (HH-BWO) to precisely adjust the hyperparameters in the DBN network. However, the HHO algorithm can easily fall into a local optimum, this drawback is overcome by HHO-BWO, which provides a fast convergence speed and avoids local optima problems.

A novel meta-heuristic optimizer called HHO and BWO is prompted by the way Harris' hawks and black widow spiders in nature locate food sources. In the initial phase of the Harris Hawks Algorithm, many hawks outbreak a hunt simultaneously to astonish it (exploration stage). Hawks may do a series of quick dives as they approach the target to startle and tire it, which reduces its chances of escaping and fleeing throughout the hunt (exploitation period). The HHO algorithm may change from exploration to exploitation and then between various exploitative phases depends on the target's energy as it is escaping. The energy required for the search can be significantly reduced by jogging. The energy of the target may be described as follows to represent its actions:

$$Energy\ (Egy) = 2E_0\left(1 - \frac{iter}{iter_{max}}\right) \quad (8)$$

Where $iter_{max}$ the greatest amount of iterations, Egy_0 represents the beginning Egy of the target, and Egy symbolizes running and escaping energy of the hunt or target at every iteration of method. The user ought to pick the value for $iter_{max}$. At every stage of this procedure, Egy_0 fluctuates at random within the range (-1, 1). When $Egy_0{}'$s value rises from (0, 1), it implies that target is reinforcing, and once it falls from 0 to -1, it denotes that the hunt is exhausted. After several trials & iterations, the energy of the fleeing target will steadily deplete. As a result, the BWOA starts with a spider search agent (population), where every spider represents a potential applicant. As partners, these early spiders try to produce a new generation. The main components of the proposed BWOA are movement and scent. The following is a description of the BWOA mathematical simulation:

Movement: Formula (9), which describes spider's movements inside the web, shows that they were both linear and spiral.

$$\vec{p_i}(n+1) = \begin{cases} \vec{p}_{best}(n) - q\vec{p}_{r_1}(n) & if\ rand() \le 0.3 \\ \vec{p}_{best}(n) - \cos(2\pi\delta)\,\vec{p}_i(n) & for\ other\ circumstance \end{cases} \quad (9)$$

Where, $\vec{p_i}(n+1)$ is the newly created location of a pursuit agent, $\vec{p}_{best}(n)$ is preceding iteration's best pursuit agent, q corresponds to a randomly generated float number, r_1 varies from one, and supreme size of pursuit agents produced by a random number, $\vec{p}_{r_1}(n)$ location of r_1 pursuit agent, δ is a randomly created float number in the interim, $\vec{p}_i(n)$ is the location of the current pursuit agent.

Scents: When spiders mate, scents play a vital role. Low scent rates in female spiders are a sign of cannibalistic behavior. Male spiders often do not like scent -poor female spiders. Another female spider might be used in place of it for low scent rates, defined as notches of 0.3 or lower. Formula (10), which monitors the spider's position, tells it to migrate away from female spiders with low scent rates. The scent rate assessment is represented by the equation.

$$\text{Scent}\ (i) = \frac{(fit_{worst} - fit_i)}{(fit_{worst} - fit_{best})} \quad (10)$$

fit_i is the present fitness value of ith pursuit agent, where fit_{worst} is present generation's worst fitness value, fit_{best} is present generation's best fitness value, etc. The proposed strategy improves fitness quality and creates a better balance among the exploration and extraction stages by updating the low scent rate pursuit agent rather than the entire pursuit agent before the following iteration.

As a result, this research extracted the features such as color and shape features by using the proposed Harris hawks – Black Widow Optimization based deep belief network (figure 5). This proposed network provides a fast convergence speed and avoids local optima problem. next that, GooLeNet's suggested Auxiliary classifier, that is covered in the next section, is given the retrieved features.

DOI: 10.6977/IJoSI.202406_8(2).0008
S. Kumar, U. Pilania, et al./ Int. J. Systematic Innovation, 8(2), 95-112 (2024)

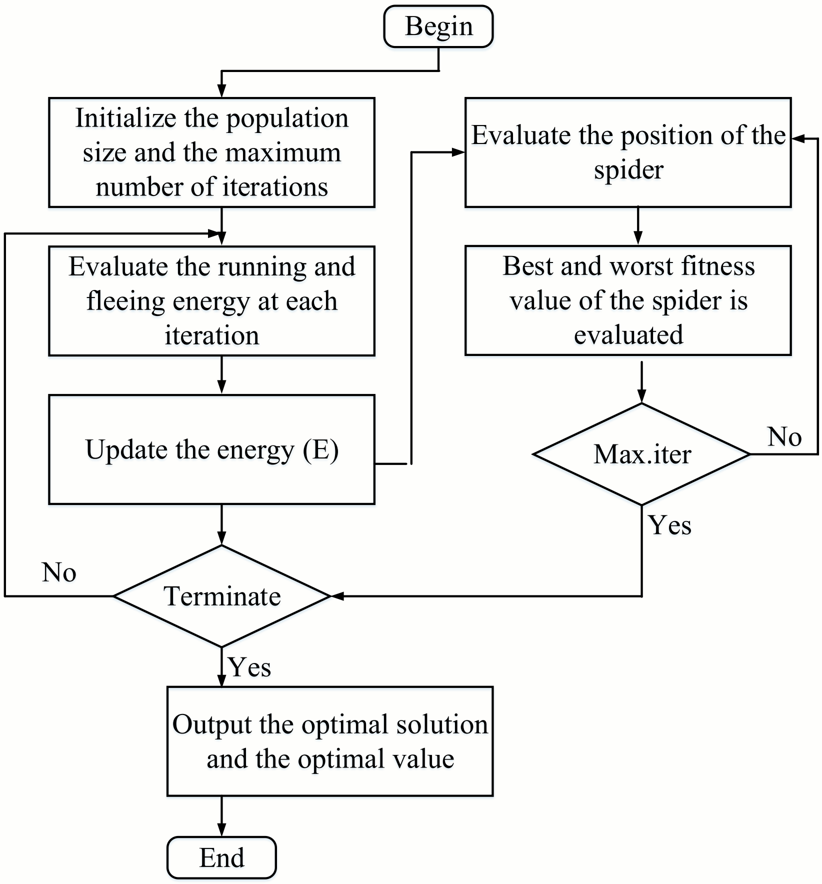


Figure 5. Architecture of the proposed HH-BWO

3.3.2 A novel auxiliary classifier for brain tumor classification

This study used an auxiliary classifier in the Google Neural Network to categorize the brain tumor. After training, a small CNN is used as an auxiliary classifier; any losses it experiences are added to the network's overall losses. GoogLeNet employs auxiliary classifiers for an extra network, in contrast to Inception v3, which utilizes them as a regularizer. In our research, the auxiliary classifier is to perform a classification based on the inputs and adds the loss calculated during the training back to the total loss of the network.

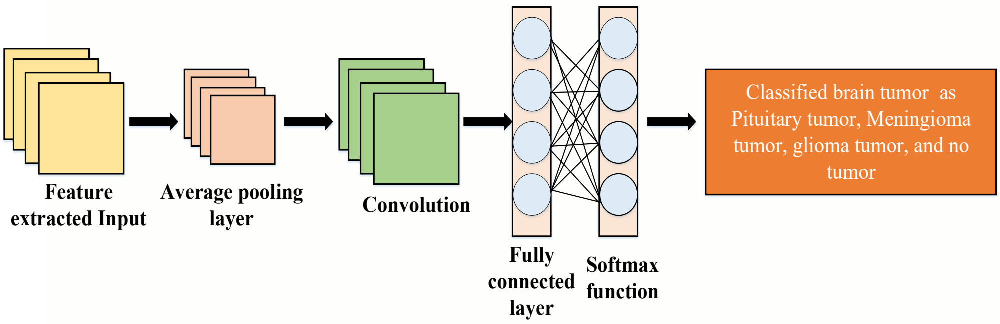


Figure 6. Proposed Auxillary Classifier

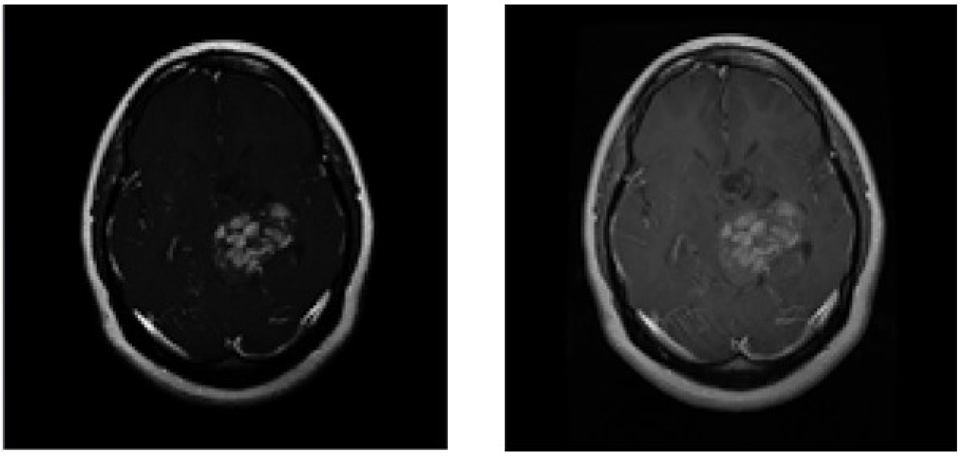
Figure 6 illustrates an auxiliary classifier, that includes layers of average pooling layers fully connected layer, and softmax function. This comprises a softmax categorization level, two fully connected layers with 1024 outputs each and 1000 outputs each, a 3×3 average pooling layer with a stride of 3, 3×3 convolutions, and 128 filters. The loss of the auxiliary classifier units is multiplied by 0.4 and then added to the overall network loss when we train the neural network. These levels offer regularization as well as assistance in overcoming the gradient vanishing issue.

The outlined auxiliary classifier is used to classify the brain tumor as a PT, MT, GT, or H, increasing efficiency and performance parameters (accuracy, precision, recall, and specificity) of brain tumor identification along with categorization. The findings of the unique optimized neural network for feature extraction and classification from brain tumors are then presented in the next section.

4. Results and discussion

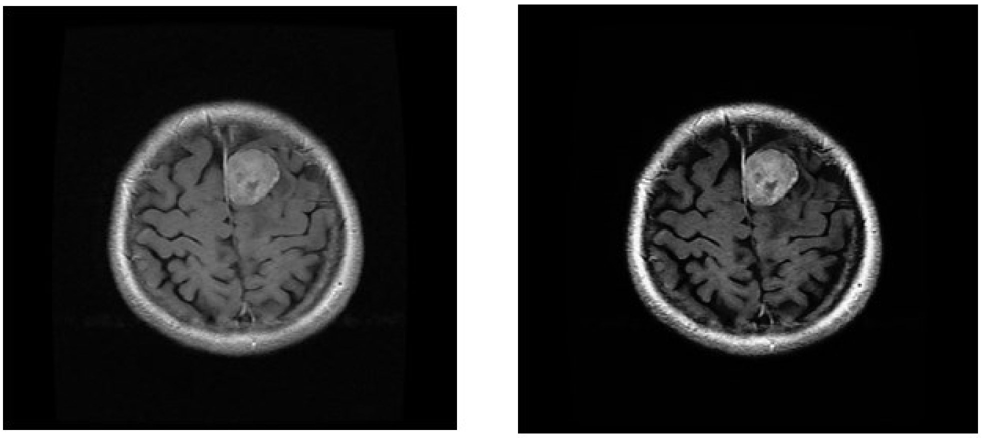
This segment, the proposed approach's performance & comparison findings are discussed in addition to the results of its execution. Python 3 is employed for implementing the results of the proposed neural network for effectively detecting brain tumors and their types.

4.1 Obtained results from the proposed approach



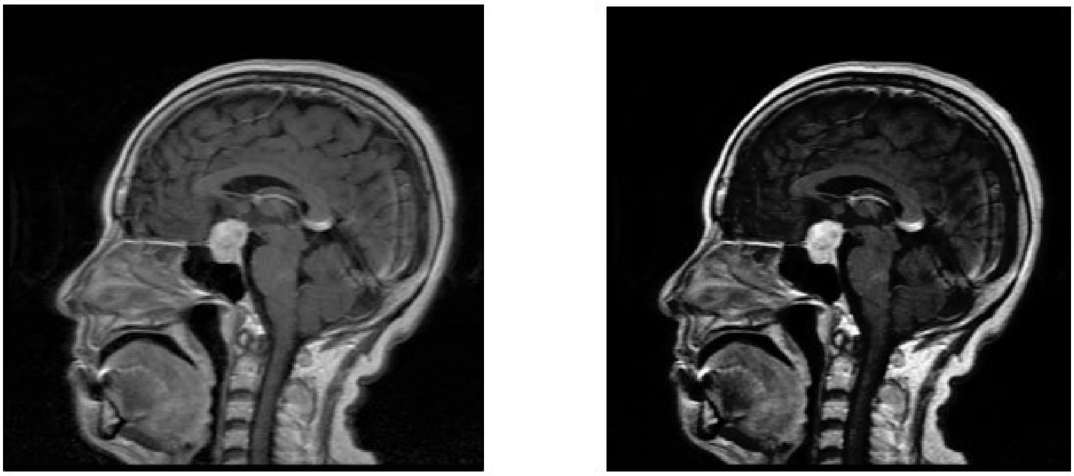
(a) (b)

Figure 7. Results of GT (a) before P-P (b) after P-P



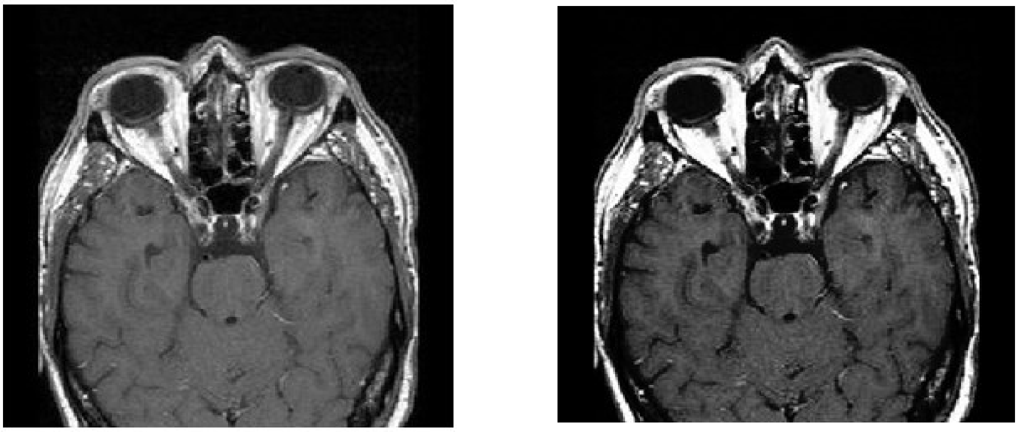
(a) (b)

Figure 8. Results of MT (a) before P-P (b) after P-P



(a) (b)

Figure 9. Results of PT (a) before P-P (b) after P-P



(a) (b)

Figure 10. Results of H (a) before P-P (b) after P-P

Figures 7 to **10** display the pre-processing results for GT, MT, PT, and H. The proposed innovative Hybrid Deep Belief Google Network (DBGN) architecture for brain tumor identification and classification is then fed these pre-processed pictures. The pre-processing procedures increase the brain tumors' accuracy in categorization.

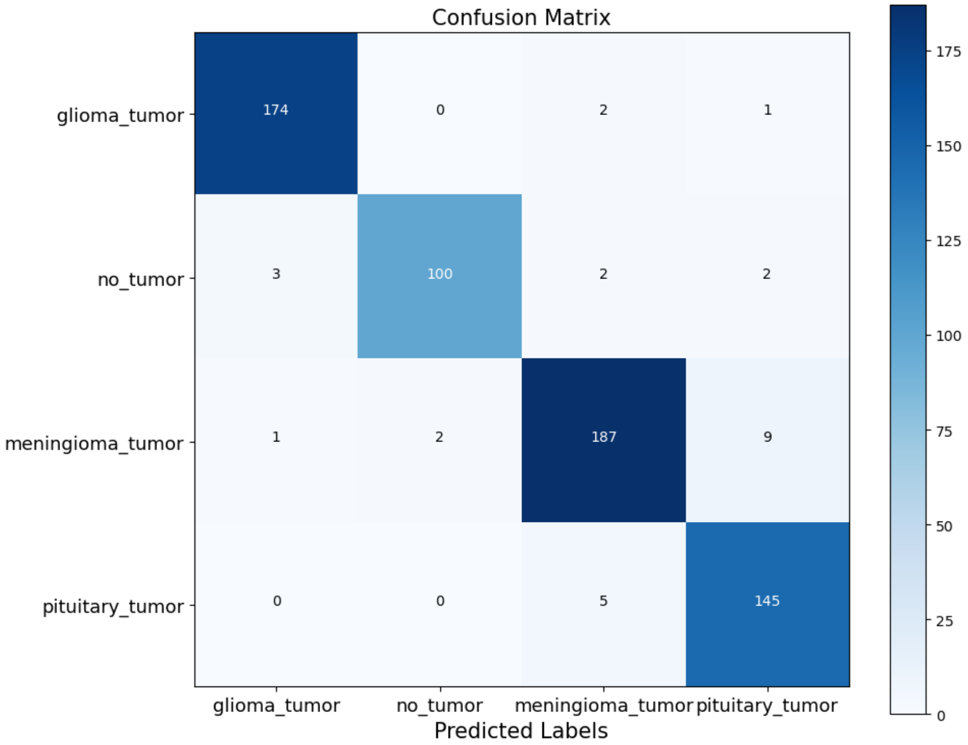


Figure 11. Confusion Matrix

Figure 11 shows the proposed auxiliary classifier's performance for detecting & categorizing brain tumors in Google Net. The brain tumor in the MRI dataset is shown in Figure 11. A confusion matrix on the main diagonal displays the properly detected brain tumor from top left to bottom right. In the other cells, known as genuine negatives or false negatives, the erroneous labels are visible. The proposed hybrid model, therefore, produces superior outcomes.

The performance of the unique strategy for classifying brain tumors is assessed using the performance of the approach we propose and several measures, including accuracy, precision, recall, sensitivity, and specificity. The calculations that follow are used to assess the A_{ccu} , P_{re} , R_{eca} and S_{pec} of various performance characteristics. Here, Tp, Tn, Fp, and Fn stands for True positive, True negative, False positive, and False negative.

$$Accuracy(A_{ccu}) = \frac{\text{Tp+Tn}}{\text{Tp+Tn+Fp+Fn}} \quad (11)$$

$$Precision\ (P_{re}) = \frac{\text{Tp}}{\text{Tp+Fp}} \quad (12)$$

$$Recall\ (R_{eca}) = \frac{\text{Tp}}{\text{Tp+Fn}} \quad (13)$$

$$Specificity\ (S_{pec}) = \frac{\text{Tn}}{\text{Fp+Tn}} \quad (14)$$

4.2 Performance Parameters

The different performance metrics of the presented innovative optimized neural network for the extraction and categorization of brain tumor feature are described in this subsection.

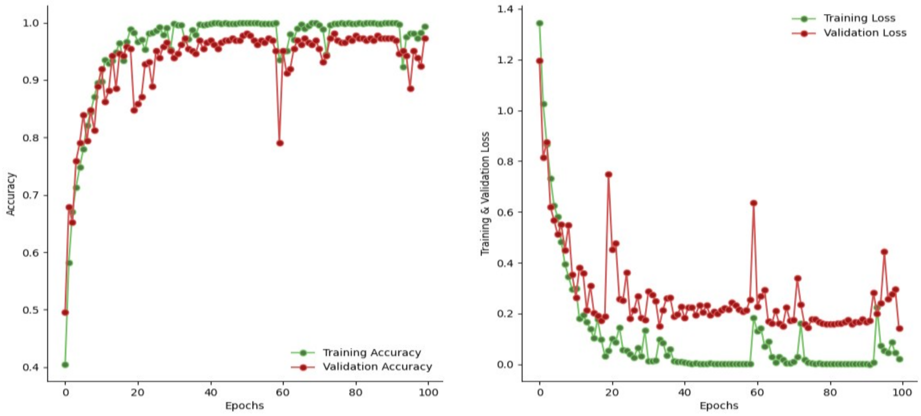


Figure 12. Training and Validation Accuracy, Loss

Figure 12 shows that at epoch 28, the training and validation accuracy scores are 0.83 and 0.9906. The training accuracy is greater than the validation accuracy when using our suggested optimization-based DBN model, proving the effectiveness of the proposed approach. At epoch 27, the loss for training and validation is 0.1747 and 0.0326, correspondingly. According to Figure 12, when employing the optimization-based DBN technique we've proposed, the training loss is lower than the validation loss.

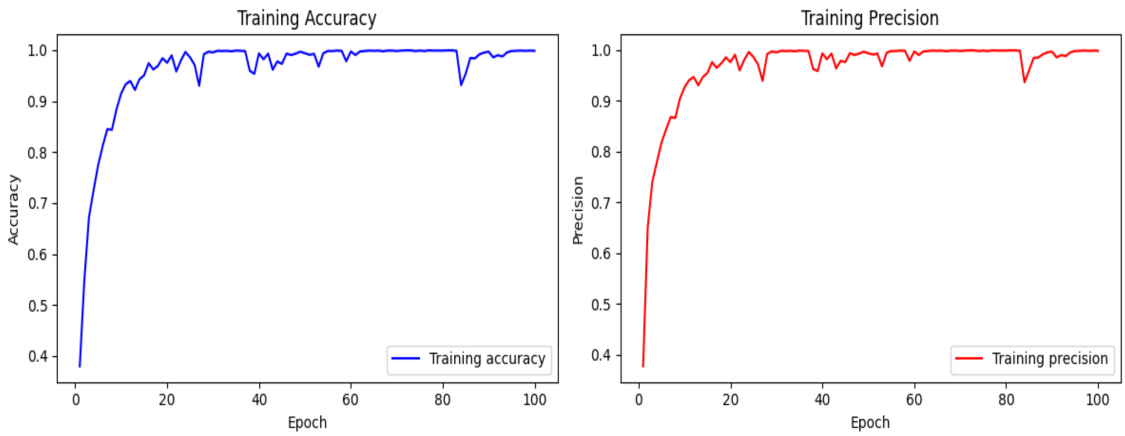


Figure 13. Training Accuracy and Precision

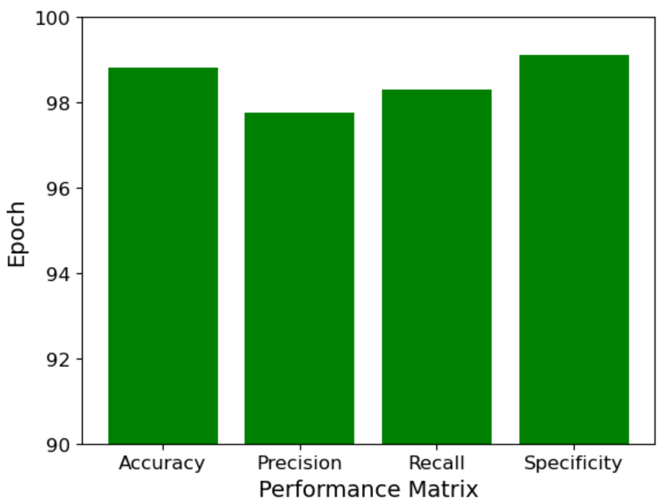


Figure 14. Performance evaluation metrics of the proposed approach

The proposed technique's performance evaluation measures are shown in Figure 14. A_{ccu}, P_{re}, R_{eca} and S_{pec} values were 98.8%, 97.75%, 98.31%, and 99.12% respectively. By adopting a cutting-edge Hybrid Deep Belief Google Network (DBGN) architecture, the performance of our suggested achieves improved accuracy, precision, recall, and specificity.

4.3 Comparison analysis

The proposed technique is compared to existing methods in this section, including, Whale Harris Hawks optimization - Deep Convolutional Neural Network (WHHO - DCNN) (Rammurthy et al. 2022), Basic CNN [34], VGG 16 Net [34], Densenet (Ozkaraca et al. 2023) and Modified CNN (Ozkaraca et al. 2023) .

Table 1. Comparison analysis on existing vs proposed approach

Techniques	Accuracy	Precision	Recall
Whale Harris Hawks optimization - Deep Convolutional Neural Network (WHHO - DCNN) (Rammurthy et al. 2022)	81.1%	-	77.8%
Basic CNN (Ozkaraca et al. 2023)	92.32%	92.25%	90.00%
VGG 16 Net (Ozkaraca et al. 2023)	91.03%	86.25%,	86.25%
Densenet (Ozkaraca et al. 2023)	90.30%	87.75%	87.75%
Modified CNN (Ozkaraca et al. 2023)	98.55%	96.0%	96.0%
Proposed Approach	98.8%	97.75%	98.31%

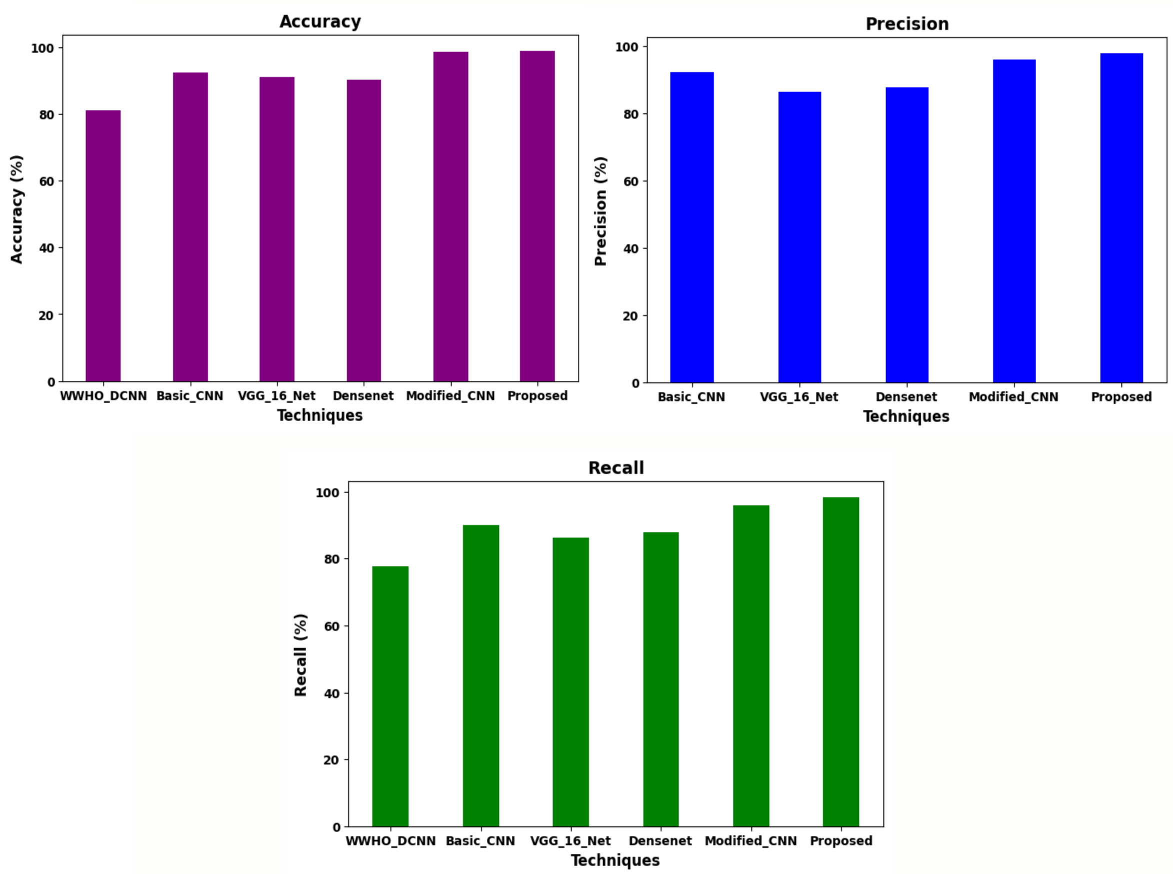


Figure 15. Comparison methods on brain tumor classification of A_{ccu}, P_{re}, and R_{eca}

Figure 15 displays the comparison of total A_{ccu}, P_{re}, and R_{eca}. Utilizing the cutting-edge Hybrid Deep Belief Google Network (DBGN) framework enhances the efficiency of the proposed technique. When compared to the baseline procedures shown in Table 1, our proposed approach achieves improved accuracy, precision, and recall.

5. Conclusion

This study proposes a unique Hybrid Deep Belief Google Network (DBGN) framework for identifying and categorizing brain tumors. The three essential processes in this innovative architecture are pre-processing feature extraction, and classification. Image enhancement, denoising, and recognition of edges have to be carried out during pre-processing step. Then, to remove features of Deep Belief Network (DBN) is proposed, moreover, to fine-tune the hyperparameters in the DBN network, this research proposed a Harris hawk – Black Widow Optimization (HH-BWO). Then, to classify the brain tumor this research utilized an Auxillary classifier in the GoogLeNet. As a result, our proposed approach provides higher performance in terms of accuracy, precision, recall, and specificity of 98.8%, 97.75%, 98.31%, and 99.12% when compared to the existing approaches.

Funding

The authors declare that no funds, grants, or other support were received during the preparation of this manuscript.

Conflict of interest

The authors declare that they have no conflict of interest.

Author Contributions

All authors read and approved the final manuscript

Data Availability Statement

Data sharing not applicable to this article, because it’s confidential.

Acknowledgments

The authors would like to thank Manav Rachna University for supporting this work.

References

Acharya, M., Alsadoon, A., Al-Janabi, S., Prasad, P. W. C., Dawoud, A., Alsadoon, G., & Paul, M. (2020, November). MRI-based diagnosis of brain tumours using a deep neural network framework, In 2020 5th International Conference on Innovative Technologies in Intelligent Systems and Industrial Applications (CITISIA) (pp. 1-5). IEEE.

Amin, J., Sharif, M., Yasmin, M., & Fernandes, S. L. (2020). A distinctive approach in brain tumor detection and classification using MRI, Pattern Recognition Letters, 139, 118-127.

Archana, K. V., & Komarasamy, G. (2023). A novel deep learning-based brain tumor detection using the Bagging ensemble with K-nearest neighbor, Journal of Intelligent Systems, 32(1).

Asad, R., Rehman, S. U., Imran, A., Li, J., Almuhaimeed, A., & Alzahrani, A. (2023). Computer-Aided Early Melanoma Brain-Tumor Detection Using Deep-Learning Approach, Biomedicines, 11(1), 184.

Babu, P. A., Rao, B. S., Reddy, Y. V. B., Kumar, G. R., Rao, J. N., Koduru, S. K. R., & Kumar, G. S. (2023). Optimized CNN-based Brain Tumor Segmentation and Classification using Artificial Bee Colony and Thresholding, International journal of computers communications & control, 18(1).

Chen, B., Zhang, L., Chen, H., Liang, K., & Chen, X. (2021). A novel extended Kalman filter with support vector machine based method for the automatic diagnosis and segmentation of brain tumors, Computer Methods and Programs in Biomedicine, 200, 105797.

Fernandes, S. L., Tanik, U. J., Rajinikanth, V., & Karthik, K. A. (2020). A reliable framework for accurate brain image examination and treatment planning based on early diagnosis support for clinicians, Neural Computing and Applications, 32, 15897-15908.

Gore, D. V., & Deshpande, V. (2020, June). Comparative study of various techniques using deep Learning for brain tumor detection, In 2020 International conference for emerging technology (INCET), 1-4, IEEE.

Irmak, E. (2021). Multi-classification of brain tumor MRI images using deep convolutional neural network with fully optimized framework, Iranian Journal of Science and Technology, Transactions of Electrical Engineering, 45(3), 1015-1036.

Jun, W., & Liyuan, Z. (2022). Brain Tumor Classification Based on Attention Guided Deep Learning Model, International Journal of Computational Intelligence Systems, 15(1), 35.

Kabir, M. A. (2020, June). Early stage brain tumor detection on MRI image using a hybrid technique, In 2020 IEEE Region 10 Symposium (TENSYMP), 1828-1831, IEEE.

Khan, M. A., Akram, T., Sharif, M., Saba, T., Javed, K., Lali, I. U., & Rehman, A. (2019). Construction of saliency map and hybrid set of features for efficient segmentation and classification of skin lesion, Microscopy research and technique, 82(6), 741-763.

Kujur, A., Raza, Z., Khan, A. A., & Wechtaisong, C. (2022). Data Complexity Based Evaluation of the Model Dependence of Brain MRI Images for Classification of Brain Tumor and Alzheimer's Disease, IEEE Access, 10, 112117-112133.

Kumaar, M. A., Samiayya, D., Venkatesan Rajinikanth, P. M., & Kadry, S. Brain Tumor Classification Using a Pre-Trained Auxiliary Classifying Style-Based Generative Adversarial Network.

Kumar, S., Pilania, U., & Nandal, N. (2023). A systematic study of artificial intelligence-based methods for detecting brain tumors, Информатика и автоматизация, 22(3), 541-575.

Kurdi, S. Z., Ali, M. H., Jaber, M. M., Saba, T., Rehman, A., & Damaševičius, R. (2023). Brain Tumor Classification Using Meta-Heuristic Optimized Convolutional Neural Networks, Journal of Personalized Medicine, 13(2), 181.

Li, J., Han, Y., Zhang, M., Li, G., & Zhang, B. (2022). Multi-scale residual network model combined with Global Average Pooling for action recognition, Multimedia Tools and Applications, 1-19.

Majib, M. S., Rahman, M. M., Sazzad, T. S., Khan, N. I., & Dey, S. K. (2021). Vgg-scnet: A vgg net-based deep learning framework for brain tumor detection on mri images, IEEE Access, 9, 116942-116952.

Malla, P. P., Sahu, S., & Alutaibi, A. I. (2023). Classification of Tumor in Brain MR Images Using Deep Convolutional Neural Network and Global Average Pooling. Processes, 11(3), 679.

Masood, M., Nazir, T., Nawaz, M., Mehmood, A., Rashid, J., Kwon, H. Y., & Hussain, A. (2021). A novel deep learning method for recognition and classification of brain tumors from MRI images, Diagnostics, 11(5), 744.

Mishra, P. K., Satapathy, S. C., & Rout, M. (2021). Segmentation of mri brain tumor image using optimization based deep convolutional neural networks (dcnn), Open Computer Science, 11(1), 380-390.

Mishra, S. K., & Deepthi, V. H. (2021). Retracted article: brain image classification by the combination of different wavelet transforms and support vector machine classification, Journal of Ambient Intelligence and Humanized Computing, 12(6), 6741-6749.

Nawaz, S. A., Khan, D. M., & Qadri, S. (2022). Brain tumor classification based on hybrid optimized multi-features analysis using magnetic resonance imaging dataset, Applied Artificial Intelligence, 36(1), 2031824.

Özkaraca, O., Bağrıaçık, O. İ., Gürüler, H., Khan, F., Hussain, J., Khan, J., & Laila, U. E. (2023). Multiple Brain Tumor Classification with Dense CNN Architecture Using Brain MRI Images, Life, 13(2), 349.

Patil, S., & Kirange, D. (2023). Ensemble of Deep Learning Models for Brain Tumor Detection, Procedia Computer Science, 218, 2468-2479.

Rammurthy, D., & Mahesh, P. K. (2022). Whale Harris hawks optimization based deep learning classifier for brain tumor detection using MRI images, Journal of King Saud University-Computer and Information Sciences, 34(6), 3259-3272.

Rammurthy, D., & Mahesh, P. K. (2022). Whale Harris hawks optimization based deep learning classifier for brain tumor detection using MRI images, Journal of King Saud University-Computer and Information Sciences, 34(6), 3259-3272.

Razzaq, S., Mubeen, N., Kiran, U., Asghar, M. A., & Fawad, F. (2020, October). Brain tumor detection from mri images using bag of features and deep neural network, In 2020 International Symposium on Recent Advances in Electrical Engineering & Computer Sciences (RAEE & CS), 5, 1-6. IEEE.

Saeedi, S., Rezayi, S., Keshavarz, H., & R Niakan Kalhori, S. (2023). MRI-based brain tumor detection using convolutional deep learning methods and chosen machine learning techniques, BMC Medical Informatics and Decision Making, 23(1), 1-17.

Sharif, M. I., Li, J. P., Khan, M. A., & Saleem, M. A. (2020). Active deep neural network features selection for segmentation and recognition of brain tumors using MRI images, Pattern Recognition Letters, 129, 181-189.

Sharif, M., Amin, J., Raza, M., Yasmin, M., & Satapathy, S. C. (2020). An integrated design of particle swarm optimization (PSO) with fusion of features for detection of brain tumor, Pattern Recognition Letters, 129, 150-157.

Solanki, S., Singh, U. P., Chouhan, S. S., & Jain, S. (2023). Brain Tumor Detection and Classification by using Deep Learning Classifier, International Journal of Intelligent Systems and Applications in Engineering, 11(2s), 279-292.

Sravan, V., Swaraja, K., Meenakshi, K., Kora, P., & Samson, M. (2020, June). Magnetic resonance images based brain tumor segmentation-a critical survey, In 2020 4th international conference on trends in electronics and informatics (ICOEI)(48184), 1063-1068, IEEE.

Toğaçar, M., Ergen, B., & Cömert, Z. (2021). Tumor type detection in brain MR images of the deep model developed using hypercolumn technique, attention modules, and residual blocks, Medical & Biological Engineering & Computing, 59(1), 57-70.

Yin, B., Wang, C., & Abza, F. (2020). New brain tumor classification method based on an improved version of whale optimization algorithm, Biomedical Signal Processing and Control, 56, 101728.AUTHOR BIOGRAPHIES

DOI: 10.6977/IJoSI.202406_8(2).0008
S. Kumar, U. Pilania, et al./ Int. J. Systematic Innovation, 8(2), 95-112 (2024)

AUTHOR BIOGRAPHIES:

Sanjeet Kumar received his bachelor's degree in Computer Applications from Govt. P G College (Kurukshetra University) Hisar and MCA from University of Delhi. He has more than 11 years of experience in teaching. Currently, he is working as Assistant Professor at Deen Dayal Upadhyaya College, University of Delhi, Delhi. His areas of interest include Programming Language, Data Structures and Algorithms, Machine Learning, and Deep Learning. He is professional member of ACM since 2013 and also an active member of iSIGCSE and ISoft.

Urmila Pilania is presently working as Associate Professor in CST Department, at Manav Rachna University, Faridabad. She has over 14 years of experience including academics & research. She has done her PhD in the area of Information Security in 2021. Dr. Urmila Pilania has published 10 papers in National & International level journals and presented 12 papers in National & International Conferences, 3 National Patents, attended various workshops & FDPs. She has also been associated with many conferences, journals as a reviewer of the paper and a member of technical committee. She is currently guiding 02 PhD research scholars. Her research area includes Computer Vision, Image Processing and Information Security.

Rajni Bala has done Ph.D. in Computer Science from School of Computer and Systems Sciences, Jawaharlal Nehru University, New Delhi. . Presently, she is working as an Associate professor at Deen Dayal Upadhyaya College, University of Delhi. Her current areas of research are machine learning, deep learning, time series analysis, and medical image analysis.

INSTRUCTIONS TO AUTHORS

Submission of papers

The International Journal of Systematic Innovation is a refereed journal publishing original papers four times a year in all areas of SI. Papers for publication should be submitted online to the IJoSI website (http://www.ijosi.org) In order to preserve the anonymity of authorship, authors shall prepare two files (in MS Word format or PDF) for each submission. The first file is the electronic copy of the paper without author's (authors') name(s) and affiliation(s). The second file contains the author's (authors') name(s), affiliation(s), and email address(es) on a single page. Since the Journal is blind refereed, authors should not include any reference to themselves, their affiliations or their sponsorships in the body of the paper or on figures and computer outputs. Credits and acknowledgement can be given in the final accepted version of the paper.

Editorial policy

Submission of a paper implies that it has neither been published previously nor submitted for publication elsewhere. After the paper has been accepted, the corresponding author will be responsible for page formatting, page proof and signing off for printing on behalf of other co-authors. The corresponding author will receive one hardcopy issue in which the paper is published free of charge.

Manuscript preparation

The following points should be observed when preparing a manuscript besides being consistent in style, spelling, and the use of abbreviations. Authors are encouraged to download manuscript template from the IJoSI website, http://www.ijosi.org.

1. *Language.* Paper should be written in English except in some special issues where Chinese may be acceptable. Each paper should contain an abstract not exceeding 200 words. In addition, three to five keywords should be provided.
2. *Manuscripts.* Paper should be typed, single-column, double-spaced, on standard white paper margins: top = 25mm, bottom = 30mm, side = 20mm. (The format of the final paper prints will have the similar format except that double-column and single space will be used.)
3. *Title and Author.* The title should be concise, informative, and it should appear on top of the first page of the paper in capital letters. Author information should not appear on the title page; it should be provided on a separate information sheet that contains the title, the author's (authors') name(s), affiliation(s), e-mail address(es).
4. *Headings.* Section headings as well as headings for subsections should start front the left-hand margin.
5. *Mathematical Expressions.* All mathematical expressions should be typed using Equation Editor of MS Word. Numbers in parenthesis shall be provided for equations or other mathematical expressions that are referred to in the paper and be aligned to the right margin of the page.
6. *Tables and Figures.* Once a paper is accepted, the corresponding author should promptly supply original copies of all drawings and/or tables. They must be clear for printing. All should come with proper numbering, titles, and descriptive captions. Figure (or table) numbering and its subsequent caption must be below the figure (or table) itself and as typed as the text.
7. *References.* Display only those references cited in the text. References should be listed and sequenced alphabetically by the surname of the first author at the end of the paper. For example:

Altshuller, G. (1998). *40 Principles: TRIZ Keys to Technical Innovation*, Technical Innovation Center.
Sheu, D. & Lee, H. (2011). A Proposed Process for Systematic Innovation, International Journal of Production Research, Vol. 49, No. 3, 2011, 847-868.

The International Journal of Systematic Innovation
Journal Order Form

Organization Or Individual Name	
Postal address for delivery	
Person to contact	Name: e-mail: Position: School/Company:
Order Information	**I would like to order ___ copy(ies) of the** *International Journal of Systematic Innovation*: **Period Start: 1st/ 2nd half ____, Year:___(Starting 2010)** **Period End : 1st/ 2nd half ____, Year:** **Price:** **Institutions: US $150 (yearly) / NT 4,500 (In Taiwan only)** **Individuals: US $50 (yearly) / NT 1500 (In Taiwan only)** (Local postage included. International postage extra) **E-mail to**: IJoSI@systematic-innovation.org or fax: +886-3-572-3210 Air mail desired □ (If checked, we will quote the additional cost for your consent)
Total amount due	**US$**

Payment Methods:
1. **Credit Card (Fill up the following information and e-mail/ facsimile this form to The Journal office indicated below)**
2. **Bank transfer**
3. **Account:** The Society of Systematic Innovation
4. **Bank Name:** Mega International Commercial BANK
5. **Account No:** 020-53-144-930
6. **SWIFT Code:** ICBCTWTP020
7. **Bank code**：017-0206
8. **Bank Address:** No. 1, Xin'an Rd., East Dist., Hsinchu City 300, Taiwan (R.O.C.)

VISA / Master/ JCB/ AMERICAN Cardholder Authorization for Journal Order

Card Holder Information

Card Holder Name	(as it appears on card)		
Full Name (Last, First Middle)			
Expiration Date	/ (month / year)	Card Type	□ VISA □ MASTER □ JCB
Card Number	□□□□-□□□□-□□□□-□□□□	Security Code	□□□ 
Amount Authorized		Special Messages	
Full Address (Incl. Street, City, State, Country and Postal code)			

Please Sign your name here _________________ (same as the signature on your card)

The Society of Systematic Innovation
6 F, #352, Sec. 2, Guanfu Rd,
Hsinchu, Taiwan, 30071, R.O.C.