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Learning and recognizing three-dimensional shapes by a neural network using solid angles

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Abstract

Three-dimensional (3D) shapes differ from two-dimensional (2D) shapes in terms of the amount of data that cat be acquired for each shape. In addition, the information that can be obtained from a 3D shape varies greatly depending on the viewing angle and posture, and there is currently no universal countermeasure for this problem. Therefore, it is difficult to acquire the level of features necessary for machine learning. To learn and recognize 3D shapes, learning approaches using images from various angles, techniques using normal vectors, and approaches based on the acquisition of the overall structure via voxelization have been studied thus far. However, these methods are not always effective because they complicate the preprocessing of data required for learning. In this paper, the author proposes a method using solid angles as a new quantitative feature for learning and recognition. The solid angle is a 3D angle corresponding to the plane angle of a 2D shape; when a point is fixed, a constant value can be obtained regardless of the posture of the object. In addition, although the calculations required to obtain this value are intensive and time consuming, they can be performed in a relatively simple manner. In this study, primitive shapes are learned and recognized using solid angles as a quantitative feature. As a result, the author demonstrates that after learning using a neural network, this method can appropriately recognize a given shape.

Keywords: Neural networks, Shape recognition, Shape registration, Solid angle.

1. Introduction

Unlike two-dimensional (2D) shapes, three-dimensional (3D) shapes inevitably have a substantial amount of characteristic data. Moreover, because one must perform appropriate processes for each encounter depending on the rotation of the object and the viewing angle, complicated processing is required, unlike that required for a 2D shape. Therefore, machine learning tends to be difficult for 3D shapes, in constant to 2D shapes (AI-SCHOLAR, 2018; Cohen et al., 2018; Fang et al., 2015; Mescheder et al., 2018).

In general, methods for learning and recognizing 3D shapes include learning approaches using images from various angles, techniques using normal vectors, and approaches based on reducing the amount of data via voxelization (Ahmed et al., 2019; Mescheder et al., 2018). However, there is no universal solution, and the amount of memory used and the complexity of preprocessing tend to make this process difficult (Wu et al., 2015).

In this study, the author demonstrates that accurate shape recognition can be achieved via learning based on neural networks using the solid angle as a quantitative feature for primitive shapes. In general, because one can express complex 3D shapes by performing Boolean operations on primitive shapes, constructive solid geometry representations (CSG) are widely used in the field of computer graphics (CG) and computer-aided design (CAD) (Fang, 2019). Therefore, a method for correctly learning and recognizing primitive shapes is required. By developing this research, it appears to be able to be utilized in methods such as CSG modeling to create complex shapes from primitive shapes (CORE CONCEPT TECHNOLOGIES INC., 2020; Hachiuma et al., 2017). Therefore, the application of this method may be effective in engineering fields that process geometry.

2. Related works

2.1. Solid angles

A solid angle, ω, comprising all the lines from a closed curve meeting at a vertex, is defined by the surface area of a sphere subtended by the lines and radius of that sphere, as shown in Fig. 1. The dimensionless unit of a solid angle is the steradian, with 4π steradians in a full sphere (Fig. 1). A Solid angle is the 3D equivalent of a 2D angle (Arecchi et al, 2007).

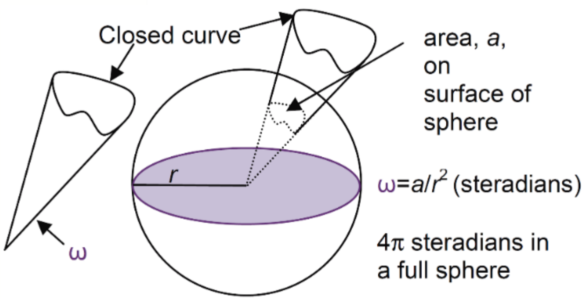

Fig. 1. Definition of a solid angle (Arecchi et al, 2007).

Because the surface area of a sphere is 4π, one can determine whether an arbitrary point belongs to the interior of a 3D figure using the solid angle (Fig. 2) (Arecchi et al, 2007; Kodama, 2018).

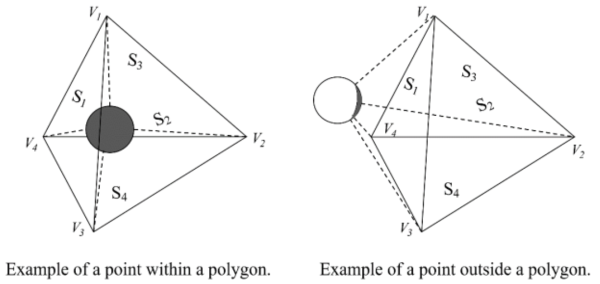

Fig. 2. Determining whether a point is within or outside a polygon based on the solid angle (Kodama, 2018).

Here, the curved surface *S* can distinguish between the front and the back. When point *O* is behind *S*, the point becomes +*P*; conversely, when point *O* is in front of *S*, the point becomes -*P* (Fig. 3) (Feng, 2019; Kodama, 2018; Kodama, 2019).

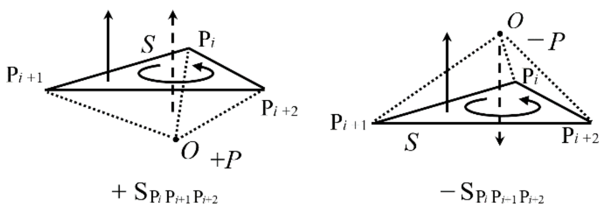

Fig. 3. Determining the obverse and reverse of a polygon (Kodama, 2018).

In a 3D shape, the input order of polygons is not uniquely determined (Research Institute for Computational Science, 2019), in contrast to a 2D shape; thus, the input can vary (Fig. 4).

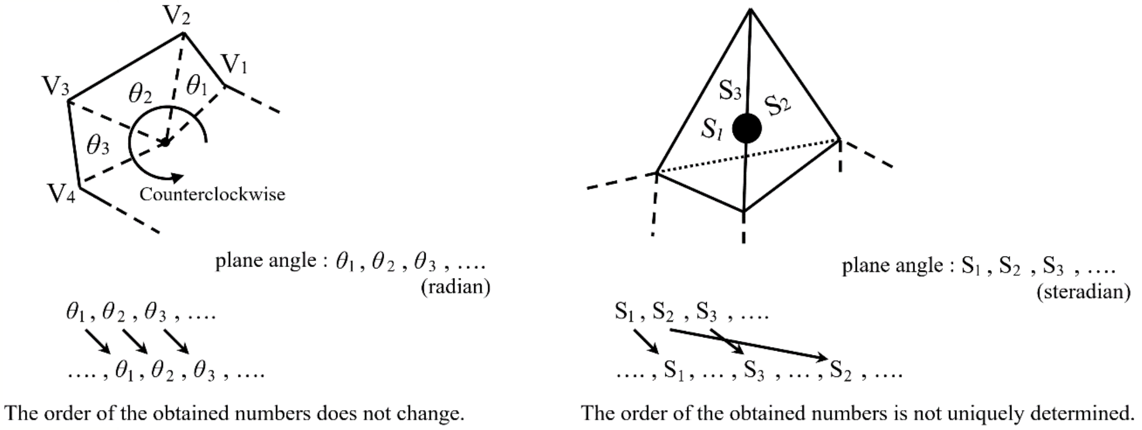

Fig. 4. Input order of data in different dimensions.

This polygon method is widely used in CG, games, and movies because it can be easily and realistically expressed by pasting a texture on the surface. This method is also widely used in general software (Kato et al., 2019).

When a solid angle is used, one can accurately perform calculations even for complicated 3D shapes such as nonconvex shapes; however, as a disadvantage, the calculations are highly time-consuming due to the use of trigonometric functions (Kawakatsu et al, 1993; Nakayama et al, 1994). Therefore, when analyzing a complex shape using a solid angle, a specialized device may be needed, such as a General-Purpose computing on Graphics Processing Units (GPGPU), depending on the size of the object and the analysis range (Kodama, 2018). However, even if the object rotates, the solid angle of the set arbitrary point does not change. Therefore, a single value is obtained regardless of the posture of the object (Fig. 5).

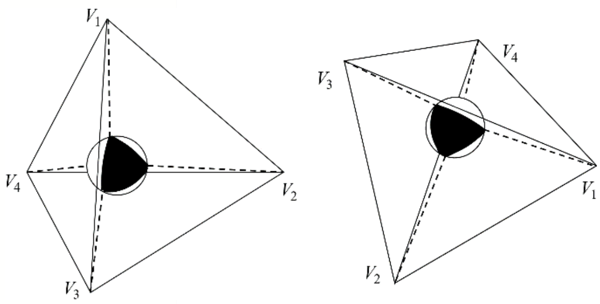

Fig. 5. The solid angle remains constant, even if the posture changes.

2.2 Learning and recognizing 3D shapes

2.2.1 Voxel-based solution

A voxel is an element of volume representing the value of a normal lattice unit in 3D space. Voxels are an extension of data pixels in 2D images and are often used for visualizing and analyzing medical and scientific data. Although voxelization has been used for a long time, its role has increased in recent years due to the continuous development of CPU and graphics hardware (Mileff and Dudra, 2019). Voxelization is frequently used because of its simplicity and ease in processing.

Using this method in combination with deep learning, a previous study proposed a technique for voxelizing a volume to 30×30×30 voxels (Fig. 6) (Wu et al., 2015). In addition, for 3D objects, various shapes can be used depending on the viewpoint. Researchers are seeking to improve identification systems by multitasking the learning process for object category identification and posture identification for rotation (Sedaghat et al., 2017).

Unfortunately, as the accuracy of a display depends on the size of each voxel or grid cell, the resolution is low and it is difficult to improve the recognition accuracy in voxelization methods (Le and Duan, 2018). If the voxels are small, a more detailed representation can be obtained; however, the memory increases in proportion to the third power, presenting a significant disadvantage (Shi et al., 2020).

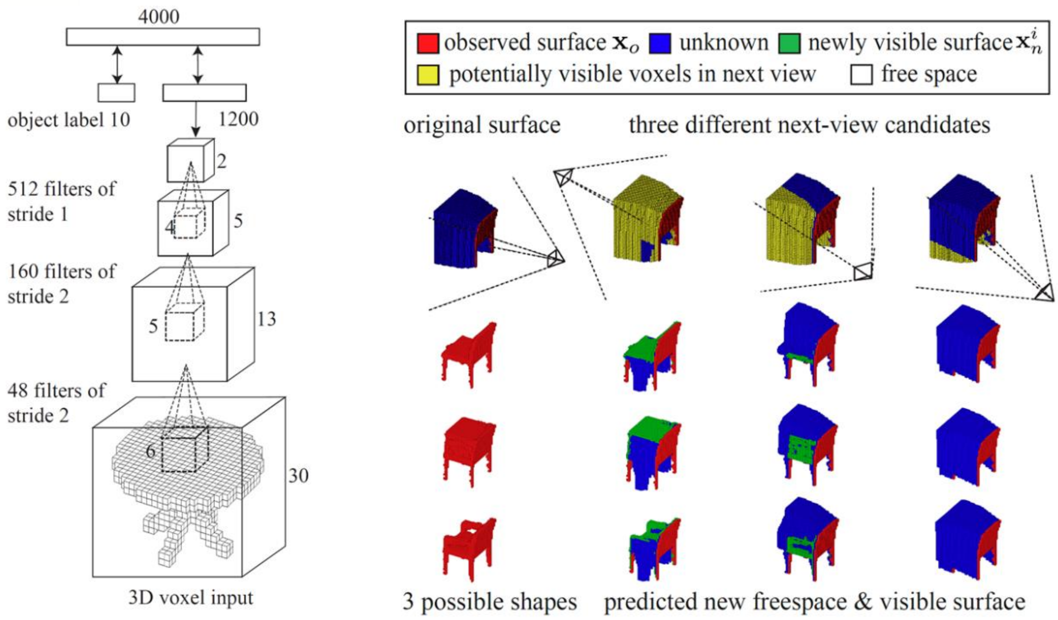

Fig. 6. Learning method based on voxelization (Wu et al., 2015).

2.2.2 Multiview solution

The multiview solution provides a method for object recognition and learning wherein 3D shapes are predicated based on 2D images obtained from various angle. Previous studies using this method have shown that the used data increase the categorical recognition accuracy by 8% compared with voxel-based methods (Su et al., 2015).

In the multiview solution, a large number of virtual cameras facing the center of gravity are arranged around the axis to create a number of 2D images and 3D shapes are compared based on these images. Subsequently, images obtained using numerous cameras around the axis are individually inputted to a convolutional neural network (CNN), and the obtained feature map is integrated using a pooling layer (view-pooling) to obtain invariance with respect to rotation around the axis (Fig. 7) (Kanezaki et al, 2018; Su et al., 2015). In recent studies, attention fusion has been conducted based on multiview images and point clouds to improve accuracy (You et al., 2018).

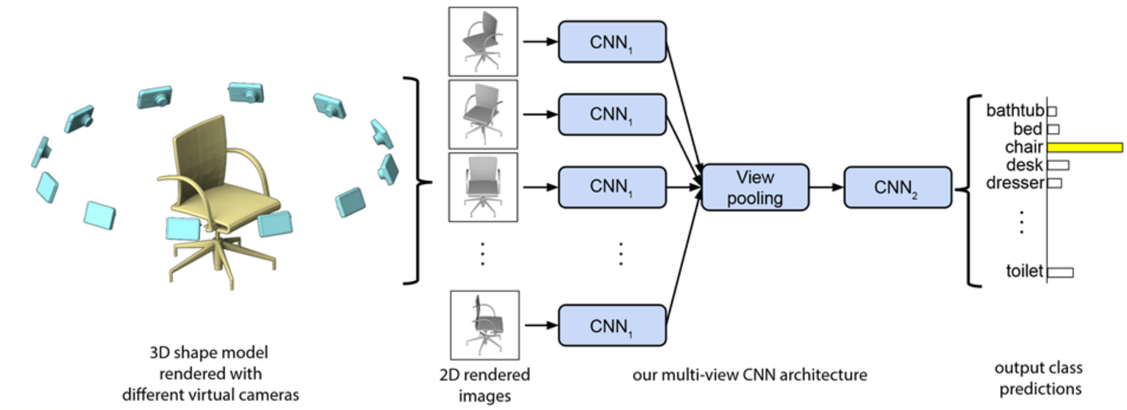

Fig. 7. Learning method based on the multiview solution (Su et al., 2015).

2.2.3 Spin-image solution

Johnson and Hebert generated a spin image by moving surrounding vertices on a cylindrical surface centered on the normal vector of a vertex (Johnson, 1997; Johnson and Hebert, 1999). They proposed a method of correspondence based on a search for similar images using the spin image compressed via primary component analysis (Fig. 8).

Currently, researchers are seeking to collate an input distance image by projecting the positional relationship with respect to peripheral points in 2D based on the normal vector at the target point of the model and acquiring features that do not depend on the posture (Deng et al, 2018).

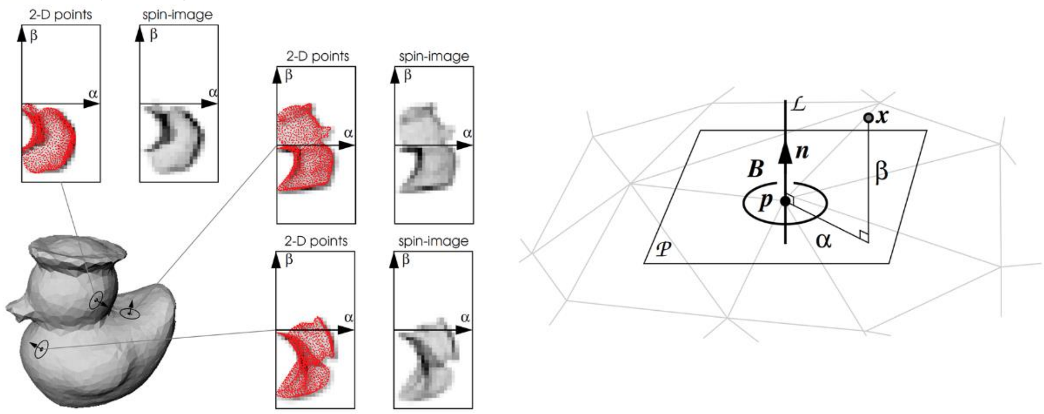

Fig. 8. Acquisition of features based on spin images (Johnson, 1997).

2.2.4 Learning and recognition through deep learning

For learning and recognition, deep learning methods have been studied based on quantitative features obtained using the voxel-based solution, multiview solution, and spin-image solution, as previously presented (Ahmed et al., 2019; Lui et al., 2019; Varma et al., 2020). However, unlike 2D shapes, 3D shapes must be observed from various directions, and one must determine whether the object remains the same when rotated (AI-SCHOLAR, 2018). In addition, the range of notable shapes may be broad, or a detailed range may be required. Therefore, it is difficult to apply methods based on CNNs (Fig. 9) (Fang et al., 2015; Jurafsky and Martin, 2020).

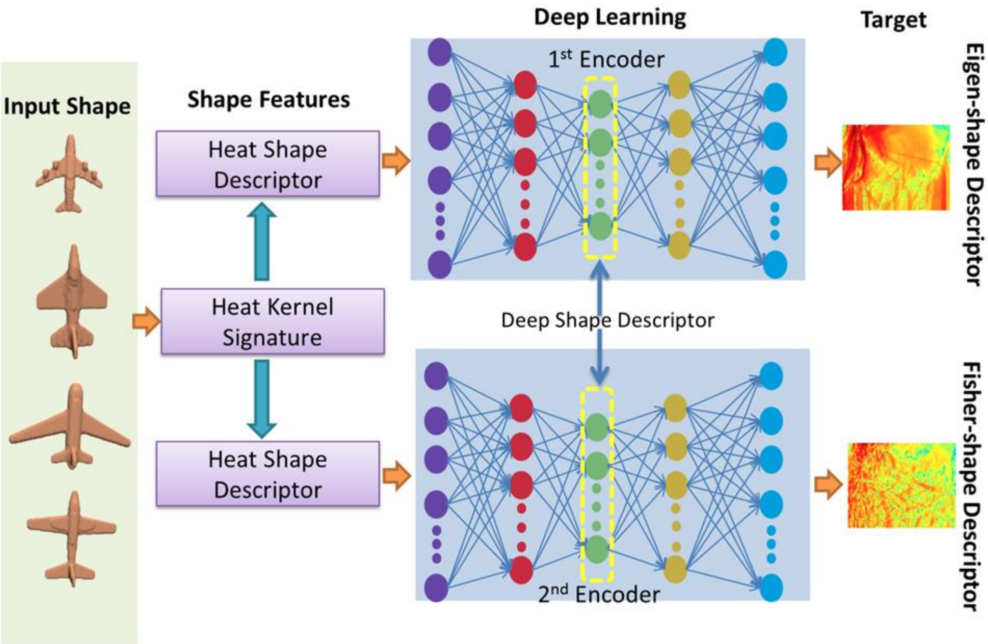

Fig. 9. Learning method for 3D figures based on deep learning (Fang et al., 2015).

2.3 Neural network

A neural network is a combination of artificial neuros, i.e., computational elements that model nerve cells. Figure 10 shows the composition of a single artificial neuron. The artificial neuron receives multiple input signals, performs appropriate calculations, and then provides an output signal.

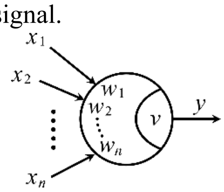

Fig. 10. Composition of an artificial neuron (Okada, 2016).

For a multi-input/single-output nonlinear element, as shown in Fig. 10, the neuron receives a multidimensional input $\boldsymbol{x} = (x_1, x_2, \dots, x_n)$ and outputs y.

In general, the processing of Fig. 10 can be described via Eq. (1).

$$y = f\left(\sum_{i=1}^{n}(w_i x_i - \theta)\right) \qquad \text{(Eq. 1)}$$

where x_i is the i-th element of x and w_i is the coupling weight corresponding to the i-th input, a parameter that represents synaptic signaling. Furthermore, θ is a threshold value. Function f is an activation function that is often expressed as a sigmoid function, such as that given in Eq. (2) (Jurafsky and Martin, 2020).

$$f(u) = \frac{1}{1+e^{-u}} \qquad \text{(Eq. 2)}$$

In general, learning is performed by constructing a network that combines numerous artificial neurons and then connecting the outputs and inputs in order. For example, a neural network that receives two input signals and provides one output signal can be built as shown in Fig. 11 (Odaka, 2016). For this type of structure, the configuration in which the signal propagates from input to output is called a feedforward network or a layered network (Odaka, 2016; Jurafsky and Martin, 2020).

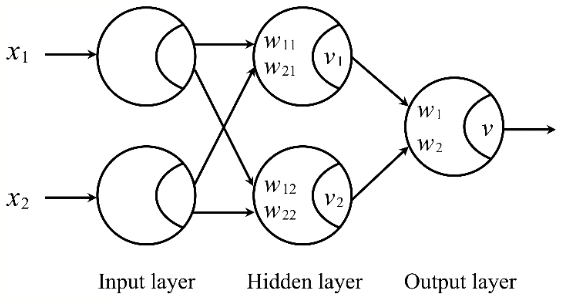

Fig. 11. Example of a feedforward network configuration (Okada, 2016).

Researchers have applied hierarchical neural networks to various tasks such as character recognition, phonological recognition, and signal processing. It has been shown that tasks such as handwritten numeral recognition can achieve almost the same performance as that obtained by manual classification. For example, previous studies have shown that a network with a total of nine layers can be applied to raw data encountered in face recognition, image recognition, handwritten characters, and word vectors in documents and can extract the structure latent in the data as a feature (Oord et al., 2016; Hinton and Salakhutdinov, 2006; Kalchbrenner et al., 2016; Zhang et al, 2016). In addition, for successful learning via neural networks with a large number of layers, researchers have developed a method for reducing the degree of freedom of coupling weights and facilitating learning by creating a task-specific coupling structure in advance (Fukushima, 2013). This approach corresponds to CNN and is often used for image recognition. CNN is a very effective method, but on the other hand, it has been pointed out that it is difficult to apply directly to numerical data such as CSV files (Takahashi et al., 2018).

For learning in multilayer networks, in principle, it has been proven that arbitrary input/output relationships can be achieved if there is one intermediate layer with a sufficiently large number of neurons (Cybenko, 1989; Funahashi, 1989).

3. Proposed method

In the proposed method, the author creates primitive shapes for multiple 3D shapes and calculate each solid angle. Thereafter, machine learning is performed using a neural network based on the obtained solid angle. It should be noted that this research assumes a preliminary step to develop into a Deep Neural Network (DNN), and for this purpose, a layered neural network has been built and verified. In other words, the effectiveness is verified by the basic configuration as based on Figure 11.

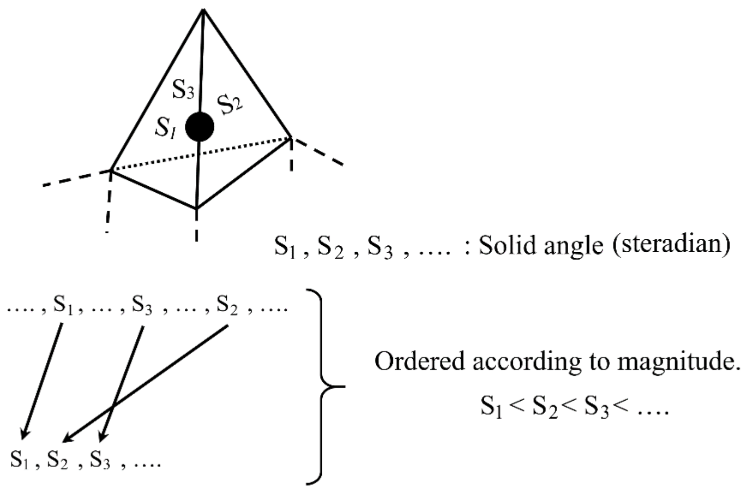

Fig. 12. Sorting of solid angles by magnitude (steradians).

As mentioned earlier, the order in which data are entered is generally not uniquely determined for 3D shapes, in contrast to 2D shapes (Fig. 4). Therefore, the author creates triangular polygons, and the solid angles of each polygon are sorted according to their magnitude, followed by the learning process (Fig. 12). In addition, in this research, the solid angle calculated for each triangle polygon centered at an arbitrary single point was used.

As an example, for the triangular pyramid shown in Fig. 13, the solid angle centered at the origin has four values, and a unique numerical sequence is obtained by applying the sorting method (Fig. 14).

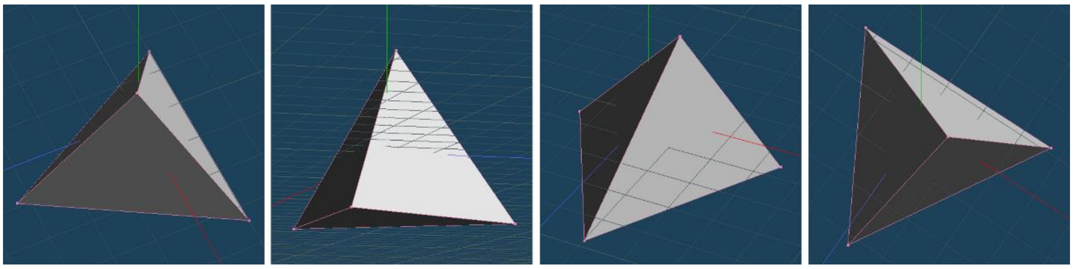

Fig. 13. Rotations of a triangular pyramid.

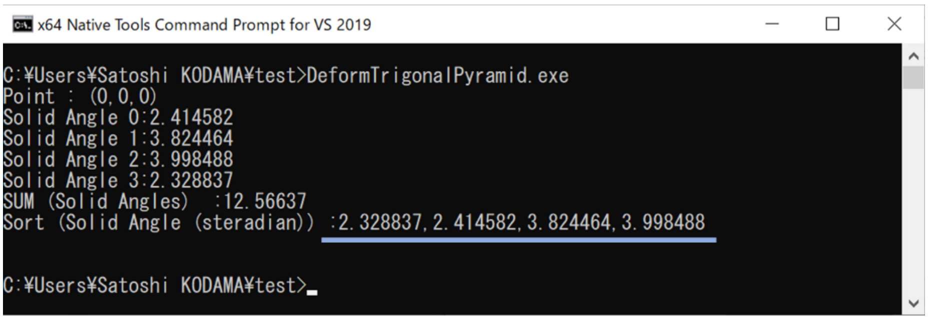

Fig. 14. Example of sorting the obtained solid angles (steradians).

Subsequently, the numerical sequence is learned by the neural network. The structure of the neural network used for learning has n inputs, single hidden layer with n and one output (Fig. 15). Here, the number of inputs n corresponds to the number of triangular polygons and x is the value of the sorted solid angle. In this configuration, a sigmoid function (Eq. 2) was used as an activation function, and the initial learning rate was set at 0.5.

Verification data were created using the same method.

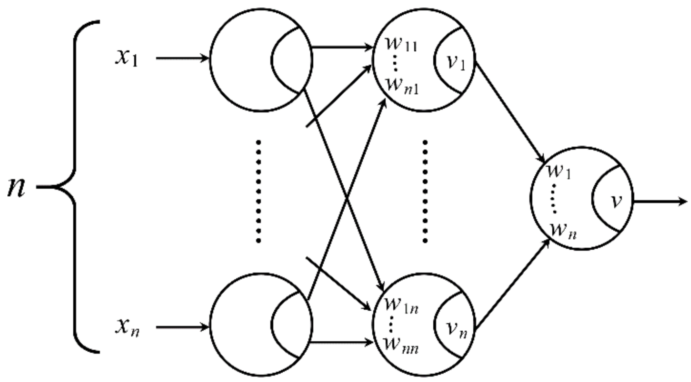

Fig. 15. Structure of neural networks used in this experiment.

4. Experiments and evaluation

The solid angles for cubes, rectangular shapes, cones, cylinders, and shapes were calculated for the learning process, which was implemented via neural networks. The effectiveness of the solid angle learning method was verified by creating a shape for verification and comparing this shape with the learning result.

As this study aimed to confirm the effectiveness of learning with solid angles as a feature, only the solid angle centered on the coordinate origin was used. The structure of the neural network used for learning changes the number of input n according to the number of triangular polygons, as illustrated in Fig. 15. Furthermore, the parameters of each cell were automatically changed by entering training data. After that, it was judged whether the result of entering the test data was correct for the parameters obtained by the training data. As mentioned above, since this is an initial verification of the feature, note that the experiment was conducted with a focus on dividing the two primitive shapes that are often used for CSG trees.

The specifications of the used equipment are shown in Table 1. No specialized devices were used in this experiment.

Table 1. Specifications of the equipment used in this experiment.

Specification	Value
OS	Windows 10 Professional (1909)
Compiler	Visual C# Compiler version 3.0.19.21801 (Visual Studio 2019)
CPU	Intel Core i7-8565U (1.8 GHz)
Memory	16 GB (DDR3)

4.1 Cube and rectangular shape (triangular polygons = 12)

The solid angle was calculated for the cubes and rectangular shapes shown in Figs. 16 and 17, respectively. Then, the solid angles of the obtained triangular polygons were rearranged in ascending order and used as learning data. In this case, because the solid angle was calculated from the coordinate origin, the solid angles are the same for each cube (Fig. 16).

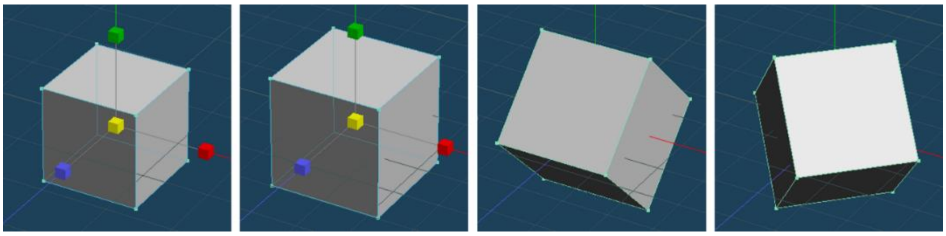

Fig. 16. Cubes utilized for learning.

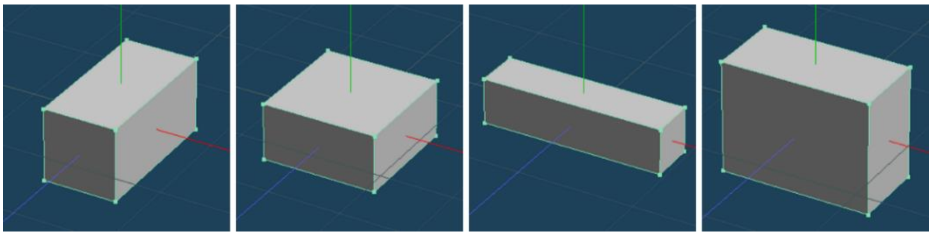

Fig. 17. Rectangular shapes utilized for learning.

For verification data, the 3D images shown in Fig. 18 were used. The verification data were processed in the same manner as the learning data, and the author verified that the shapes were correctly identified. The recognition rates based on the learning results are shown in Table 2.

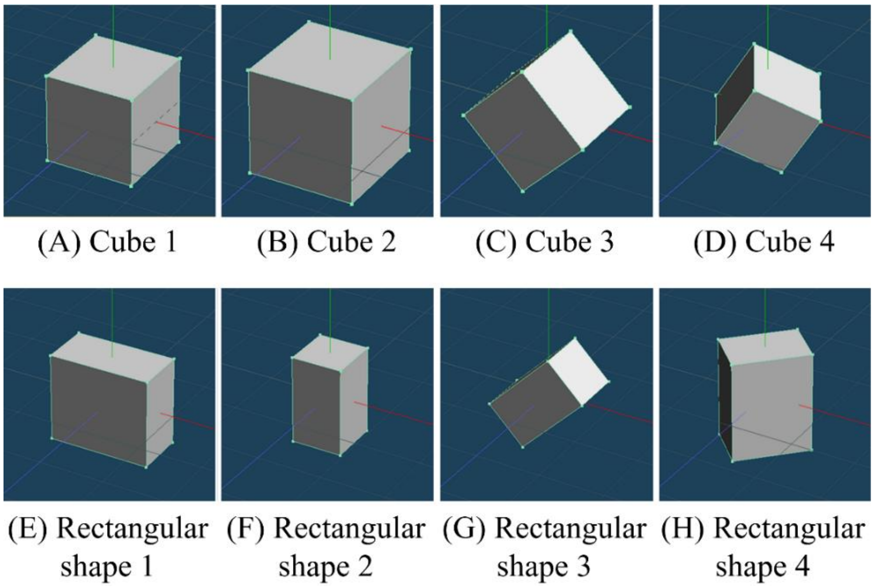

Fig. 18. Solid shapes for validation.

Table 2. Recognition rates of 3D shapes for verification.

3D shape	Correct identification rates (%)
(A) Cube 1	99.290124
(B) Cube 2	99.290124
(C) Cube 3	99.290124
(D) Cube 4	99.290124
(E) Rectangular shape 1	99.609371
(F) Rectangular shape 2	99.187627
(G) Rectangular shape 3	99.187628
(H) Rectangular shape 4	99.187628

4.2 Cone and rectangular shape (triangular polygons = 12)

The solid angle was calculated for the cones and rectangular shapes shown in Figs. 19 and 20, respectively. Then, the solid angles of the obtained triangular polygons were rearranged in ascending order and used as learning data.

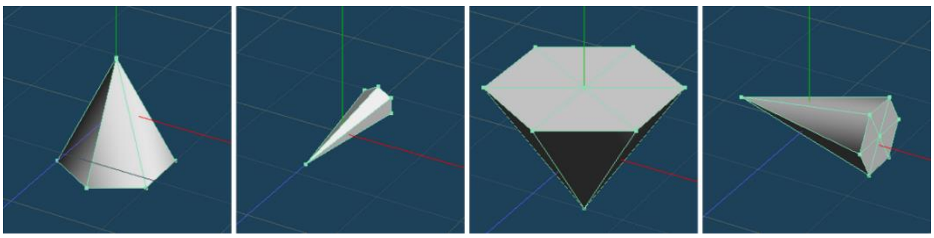

Fig. 19. Cones utilized for learning.

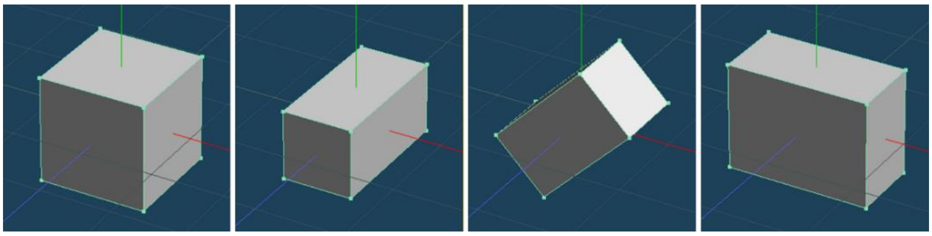

Fig. 20. Rectangular shapes utilized for learning.

For verification data, the 3D images shown in Fig. 21 were used. The verification data were processed in the same manner as the learning data, and the author verified that the shapes were correctly identified. The recognition rates based on the learning results are shown in Table 3.

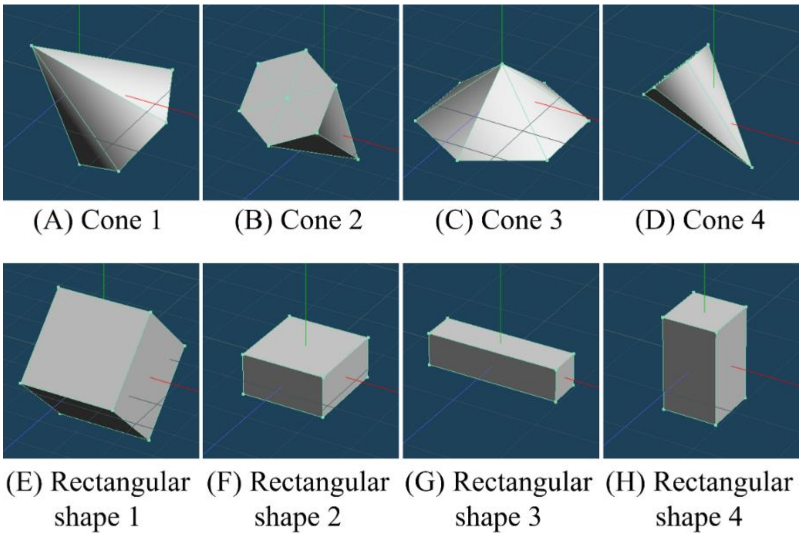

Fig. 21. Solid shapes for validation.

Table 3. Recognition rates of 3D shapes for verification.

3D shape	Correct identification rates (%)
(A) Cone 1	99.812166
(B) Cone 2	99.900417
(C) Cone 3	99.324063
(D) Cone 4	99.885613
(E) Rectangular shape 1	99.949864
(F) Rectangular shape 2	98.970878
(G) Rectangular shape 3	97.931441
(H) Rectangular shape 4	99.792057

4.3 Cone and cylinder (triangular polygons = 24)

The solid angle was calculated for the cones and cylinders shown in Figs. 22 and 23, respectively. Then, the solid angles of the obtained triangular polygons were rearranged in ascending order and used as learning data.

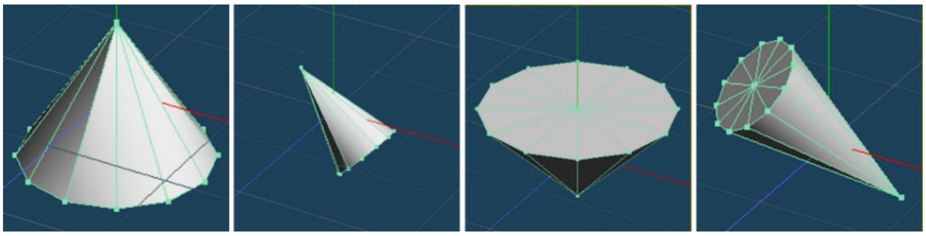

Fig. 22. Cones utilized for learning.

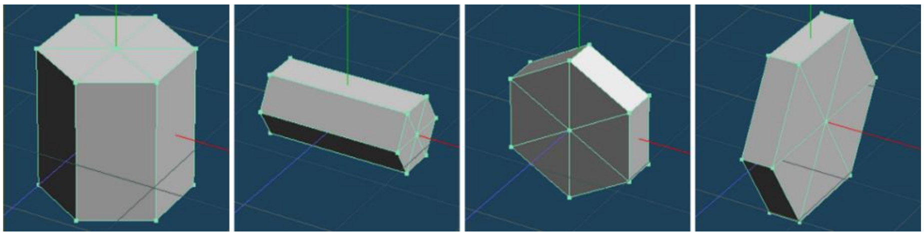

Fig. 23. Cylinders utilized for learning.

For verification data, the 3D images shown in Fig. 24 were used. The verification data were processed in the same manner as the learning data, and the author verified that the shapes were correctly identified. The recognition rates based on the learning results are shown in Table 4.

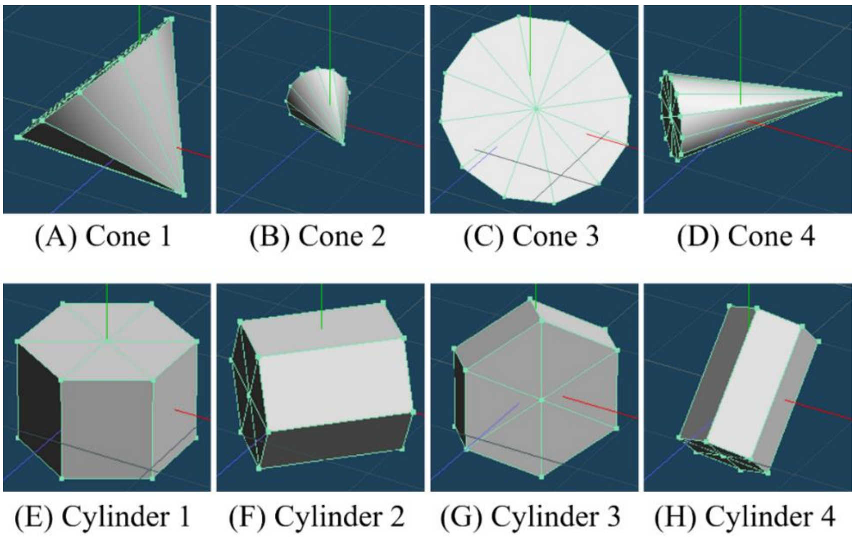

Fig. 24. Solid shapes for validation.

Table 4. Recognition rates of 3D shapes for verification.

3D shape	Correct identification rates (%)
(A) Cone 1	98.864965
(B) Cone 2	99.549863
(C) Cone 3	99.995699
(D) Cone 4	99.988801
(E) Cylinder 1	99.925257
(F) Cylinder 2	99.925258
(G) Cylinder 3	98.021626
(H) Cylinder 4	99.999792

4.4 Cylinder and sphere shapes (triangular polygons = 40)

The solid angle was calculated for the cylinders and spheres shown in Figs. 25 and 26, respectively. Then, the solid angles of the obtained triangular polygons were rearranged in ascending order and used as learning data.

For verification data, the 3D images shown is Fig. 27 were used.

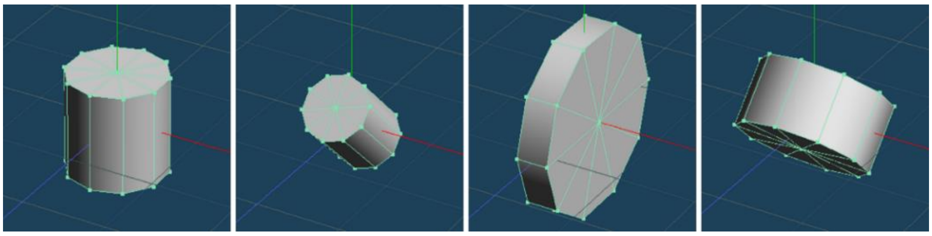

Fig. 25. Cylinders utilized for learning.

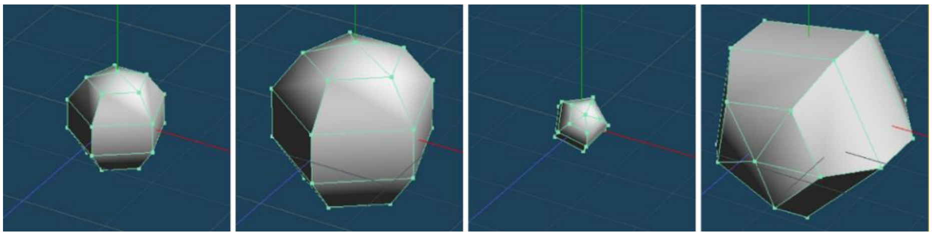

Fig. 26. Spheres utilized for learning.

The verification data were processed in the same manner as the learning data, and the author verified that the shapes were correctly identified. The recognition rates based on the learning results are shown in Table 5.

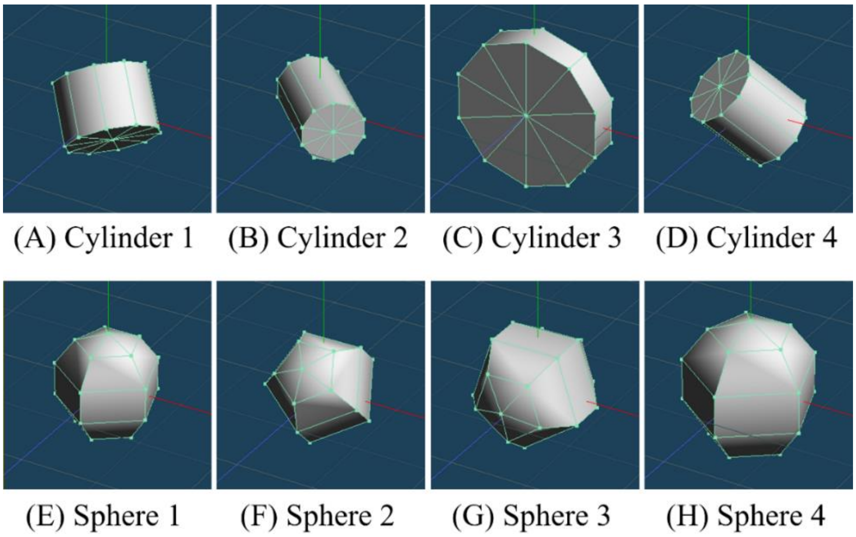

Fig. 27. Solid shapes for validation.

Table 5. Recognition rates of 3D shapes for verification.

3D shape	Correct identification rates (%)
(A) Cylinder 1	97.614127
(B) Cylinder 2	99.739156
(C) Cylinder 3	99.608418
(D) Cylinder 4	98.213890
(E) Sphere 1	98.472752
(F) Sphere 2	99.986135
(G) Sphere 3	99.999984
(H) Sphere 4	98.472755

5. Conclusion

Using the solid angle as a quantitative feature of 3D shapes, it was possible to identify a given shape with a high recognition rate. Therefore, learning based on a neural network using a solid angle as a quantitative feature is an effective means for recognizing 3D shapes.

In contrast to conventional methods, this method utilizes solid angles, and one can easily extract feature quantities without requiring a setup with virtual cameras or positional relationships for each point, as is needed for conventional learning methods. In addition, although the operations for the solid angle are time-consuming, the processing is relatively simple.

6. Future work

This study primarily focused on confirming the effectiveness of learning using solid angles; thus, primitive 3D shapes were evaluated. Furthermore, because this learning employed a small-scale neural network, experiments were conducted on polygons with a relatively small amount of data. Therefore, in this experiment, it was possible to verify without using special devices, but when expanding it in the future, it is necessary to consider the use of device such as GPGPU.

In general, complex 3D shapes require a large amount of data. In addition, as there are various methods for expressing 3D shapes, one must be able to recognize a figure using various data representations.

In the future, evaluations of more complex shapes will be required. As the amount of data grows with increasing complexity, further learning and evaluation using deep learning or similar methods must be performed. In addition, it is necessary to consider its application to CNNs. Furthermore, the use of solid angles is time-consuming for complex 3D shapes; therefore, the overall processing time should be assessed.

By advancing this research, it is thought that shape recognition from a point cloud will be possible by Light Detection and Ranging (LiDAR), Sound Navigation and Ranging (SONAR) 3D mapping, etc., and its application in the industrial field is expected to expand.

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Factors of adoption of artificial intelligence and internet of medical things amongst healthcare workers: a descriptive analysis

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Abstract

The technologies like Artificial Intelligence (AI) and the Internet of Medical Things (IoMT) have revolutionized the healthcare system. The Covid-19 pandemic has been a major force behind this revolutionary technology usage. This study finds the challenges in the adoption of this new knowledge i.e. in the adoption of AI and IoMT by the healthcare workforce based on self-designed questionnaires having questions on an interval scale to identify the challenges in the adoption of these technologies. This research was conducted from July 2020 to April 2021, taking a sample of 350 healthcare workers inclusive of doctors and paramedical staff however only three hundred respondents filled the questionnaire. Different challenges have been found for adopting AI and IoMT via an absence of a regulatory Framework; unexplained return on investment in absence of research with low funding, and Huge Data and Operational Mediocrity with all-time processing requirements are challenges for the adoption of these technologies. The finding of the study suggests better equipped and technologically aware healthcare workers for the betterment of services, especially in tough times like the Covid-19 pandemic.

Keywords: Artificial Intelligence (AI), Internet of Medical Things (IoMT), Workforce, healthcare ecosystem, Challenges

1. Introduction

With the rapid growth of medical science, it is difficult to meet all the medical requirements by using traditional methods. The Indian Healthcare sector has a projection of 372 billion by 2022. The global IoMT market stood at a value of $22.5 billion in the year 2016 and growth is anticipated to be $72.02 billion by 2021 (Nikhila, 2021), growing at an annual rate of 26.2 % (Frost & Sullivan. (2017). In this growth two technologies majorly contributes to Artificial Intelligence (AI) & Internet of medical things (IOMT). Furthermore, there is pressure on world healthcare systems owing to the escalations of chronic diseases and scarcity of resources (Lassalle et al., 2004). Artificial Intelligence simply represents the intelligence of machines and the separation of computer science that targets to generate it (Murali & S 2018). Medical Artificial intelligence is principally associated with the creation of AI Programs that execute identification and make therapy commendations, but working on only these areas was not enough, the AI scope in the healthcare system is much broader (Barrett, 1996). After that Artificial Intelligence in Medical (AIM) redefined its priorities and started a quiet revolution “evidence-based medicine”. The key problem area is a slower pace of system which transfers proofs to clinical practices and as result, clinical trial data keeps on mounting. A quick way is needed to access such guidelines and implement them to practice and come up with own experiences to help to make the system better. AI systems depend on the availability of large amounts of data. This poses a major impediment to building indigenous AI interventions in India.

Datasets for healthcare in India are fragmented, dispersed, and incomplete. Current AI experiments are dependent on historical data available from select hospitals or research institutes. The trouble with historical data, as has already been well documented in existing studies on AI, is that it will, by definition, reflect certain societal structures of discrimination (Gershgorn, 2018). Inadequacy of required data infrastructure is there in most healthcare organizations. IoMT provides connectivity between medical science and technology. Development and use of connected and distributed medical devices have brought the advent of IoMT which is bringing in both likely applications and abundant challenges (FernándezMaimó et al., 2019). IOMT is capable to provide more accurate results in the diagnosis. It has a low maintenance cost and makes the cure comfortable. Protection and security are more troublesome in the IoMT setting because clients, as well as unapproved articles, could get information (Miorandi et al., 2012). Real-time data of patients with the help of smartphones can be collected by doctors without visiting the patient physically (Venkatesh, 2019; Dash, 2020). It provides direct access to health reports over smartphone applications and provides an option to send them to the doctor. It prevents chronic illness. With this m- health service one can reach easily the standard of medical services and quality of medication as per patient needs (Dong, n.d.).

An enormous number of medical care experts and service providers recognize the significance of specialized medical services technology advancements. Contemporary medication cannot proceed in the earlier era any longer. The unbelievable transferal in the innovation area has stunned everybody out of their astuteness. A few quickly developing advances are merging to impact the direction of IoT in medical services. There are a few difficulties in advance improvement, healthcare delivery just as issues identified with protection of information, advanced gap, the job of government and different partners, conduct and selection by clinical specialists and emergency clinics.

In this research paper, researchers have examined mainly the challenges of Artificial intelligence and Internet of Medical Things (IoMT) adoption in the Indian healthcare ecosystem by the healthcare workforce.

2. Healthcare workforce & emerging technologies (artificial intelligence (ai) &the internet of medical things (iomt) in healthcare system

As per a report published by WHO in 2006, “This report defines health workers to be all people engaged in actions whose primary intent is to enhance health” (The World Health Report, 2006). A healthcare worker, either directly or indirectly, deliver care and services to the sickening and ailing. They do it straight as nurses &doctors or incidentally as assistants, helpers, laboratory technicians, or even medical waste handlers (Joseph and Joseph, 2016). The international classification of HCWs includes: “generalized medical practitioners, specialist medical practitioners, professionals in nursing, professionals in midwifery, professionals in traditional and complementary medicine, practitioners in paramedical, professionals like dentists, pharmacists, professionals in environmental and occupational health, and professionals in hygiene, professionals in physiotherapists, dieticians and nutritionists, audiologists, and speech therapists, optometrists and ophthalmic opticians, medical and pathology laboratory technicians, paramedical technicians and assistants, medical and dental prosthetic technicians and their assistant or aides’ (Occupation group, (n.d.)in Mohanty, Kabi, and Mohanty, 2019). jWan et al., (2019) defined AI: as “Computers which perform cognitive tasks, usually associated with human minds, particularly learning and problem-solving" (p.10). Medical artificial intelligence is primarily concerned with the construction of AI programs that perform diagnoses and make therapy recommendations. Medical AI is based on representative replicas of ailment units and their association with patient factors and clinical indicators (Clancey and Shortliffe, 1984). “AI is concerned with methods of achieving goals in situations in which the information available has a certain complex character (Haefner, Wincent, Parida, & Gassmann, 2021). The methods that have to be used are related to the problem presented by the situation and are similar whether the problem solver is human, a Martian, or a computer program” (McCarthy, 1998). AI is mainly based on algorithms and models as a technique that is designed based on scientific findings such as math, statists, and biology (Li et al., 2019.). Advancements leading to human-level AI can be estimated by the negligible portion of these positions that can be acceptably performed by machines (Nilsson et al., 2017; Uden and He, 2017).

"The Internet of Medical Things (IoMT) labels the interconnection of communication-enabled medical-grade devices and their incorporation to wider-scale health networks to improve patients' health" (Gatouillat et al., 2018; R. et al., 2020). The healthcare management system is simplified by the Internet of Medical Things making it more efficient and real (Islam, et al., 2015). It facilitates information transfer while transferring patients from one hospital to another (Joyia et al., 2017) ensuring timely and cost-efficient treatment to patients (Fischer & Lam, 2016). The Cloud computing process ensures this information sharing (Guo, Kyo&Sahama, 2012; Mell and Grance, 2011; Chang, Chiu, and Ramakrishnan, 2009). Wang and Tan (2010) and Lohr (1991, p. 21), proposed that healthcare quality is "the degree to which healthcare services for individuals and population increases". Guo, Kyo&Sahama, 2012) have considered a cloud-based platform to provide healthcare organizations with software services, a program development environment, and hardware and computational resources.

3. Role of disruptive technologies in delivering healthcare quality

Donabedian's (1988) theory stipulates that the interpersonal aspect of care plays a very important role in determining the satisfaction patients derive from health care. For a patient to be satisfied with health care delivery he should have a positive judgment towards every aspect of the quality of care delivered especially as it concerns the interpersonal side of health care. As per Donabedian (1980, p. 5), healthcare quality can be defined as "the application of medical science and technology in a manner that maximizes its benefit to health without correspondingly increasing the risk". Schuster, McGlynn& Brook (1998), p. 518) added that one of the features of decent healthcare quality is "providing patients with appropriate services in a technically competent manner, with good communication, shared decision making, and cultural sensitivity". It is the possibility of anticipated health results and is consistent with the present specialized information. Leebovand Scott, 2003), p.4) argued that healthcare quality means "doing the right things right and making continuous improvements, obtaining the best possible clinical outcome, satisfying all customers, retaining talented staff, and maintaining sound financial performance". Modern technology adoption is increasingly migrating to documenting patient interactions and information management. The term disruptive technologies was coined by Christensen (1997) and "refers to a new technology having lower cost and performance measured by traditional criteria, but having higher ancillary performance" (UTTERBACK and ACEE, 2005). "Das enable a larger population of less-skilled people or providers with less training to do things in a more convenient lower-cost setting, which historically could only be done by specialists in less convenient settings" (CN, 1996; Christensen, Bohmer, and Kenagy, 2000). Jonsson et al., (2002, p.218) have associated technology with healthcare as "broadly defined to include the drugs, devices, medical and surgical procedures used in health care, as well as measures for prevention and rehabilitation of disease, and the organizational and support systems in which health care is provided." Assen (2011) stated that operational excellence is the design and management to maximize operating profits through the constant operation of excellent production and delivery system that offers products and services to customers at the right value. Patient interaction and management of information are done via software-as-a-service (Saas) apps these days (Oh et al., 2015) enhancing the experience quality (Lemke, Clark, and Wilson, 2010). AI helps patients to move, communicate and decode neural activities on an individual basis AI utilized new technologies are showing excellent results in the calibration of mentally and emotionally fragile patients (Meghdari&Alemi, 2018). Further Istepanianet al., (2011) in their research introduced a unique concept of IoT in medical health as a highly beneficial tool for medical health. There is great optimism that the application of artificial intelligence (AI) can provide substantial improvements in all areas of healthcare from diagnostics to treatment. There is advancement in the healthcare industry like technology Internet of Medical Things (IoMT), Artificial Intelligence (AI), Machine Learning (ML), Big Data, Mobile Apps, and Advanced Sensors (Venkatesh, 2019; Laurenza et al., 2018). The foundations of technical revolution and their association with various types of healthcare services have been identified by Romeira et al. (2009). There is a digital disruption in healthcare service innovation (Ford et al, 2017) which is good for the future of healthcare (Thimbleby, 2013) but to realize efficiency gain, the costs aspects can't be neglected (Williams et al., 2008). It is generally believed that AI tools will facilitate and enhance human work and not replace the work of physicians and other healthcare staff as such. AI is ready to support healthcare personnel with a variety of tasks from administrative workflow to clinical documentation and patient outreach as well as specialized support such as in image analysis, medical device automation, and patient monitoring (Bohr A, Memarzadeh K 2020). There is advancement in the healthcare industry like technology Internet of Medical Things (IoMT), Artificial Intelligence (AI), Machine Learning (ML), Big Data, Mobile Apps, and Advanced Sensors (Venkatesh, 2019; Laurenza et al., 2018). The foundations of technical revolution and their association with various types of healthcare services have been identified by Romeira et al. (2009). There is a digital disruption in healthcare service innovation (Ford et al, 2017) which is good for the future of healthcare (Thimbleby, 2013) but to realize efficiency gain, the costs aspects can't be neglected (Williams et al., 2008).

These practical health care models are connected digitally leading to better delivery of value for patients and convenience to doctors. healthcare technologies will change the roles of healthcare workers and government (Mitchell &Kan, 2019) and a new framework for implementation of healthcare monitoring has to be worked upon Xu et al., (2015). Rong, (2020) has appreciated the tremendous potential of AI in biomedicine. Health care professionals, clients, managers, payers, policymakers, and certification staff's service-quality viewpoints in healthcare organizations have also been explored (Ali Mosadeghrad, 2014; Greco et al., 2020). Improvement in the safety of the patient by lesser errors in medication and minimization of adverse drug reactions as well as better practice guidelines acquiescence are the results of health information technology (Alotaibi and Federico, 2017). Even they can be reached through mobile phones, especially for those patients who stay out-station (Rajkumari, 2014) thus IoMT has been used in Better Dispersal of Health Care Methods and Improving Health Care Systems. A holistic approach is needed for the transformation of traditional healthcare to digitalized healthcare (Kraus et al., 2021).

4. Adoption of ai & iomt in healthcare: review of challenges

AI is a fundamentally Developing market in the field of healthcare and proven medical AI can play an important role in helping doctors and patients to deliver healthcare much more professionally in the 21st century (Murali& S, 2018; Vatandsoost&Litkouhi,2018). The variety of solicitations of AI and AI-mediated technologies in Medicine and Health Care is vast and rapidly increasing, with many powerful potential (positive and negative) results, which may affect the human being and society at all scales (van Hartskamp et al.,2019); Emilio Gómez-González et al., (2020). AI has a prominent perspective to encourage the shift of conventional healthcare into equitable cooperation among patients and health providers by investigating the immense quantities of data recorded by medical organizations and patients in each instant (Rayan, 2019).

AI systems enable decision-making in doctors (Mahapatra, Bozorgtabar, & Garnavi, 2019) In this research the author wrote about the overview impact of AI in the Indian healthcare system and wrote about the AI applications in stroke, in the three major areas of early detection and diagnosis, treatment, as well as outcome prediction and prognosis evaluation (Jiang et al., 2017). Research has resulted in the statement that explains the ability of the model's decision is an important component of AI systems, especially when it comes to healthcare since doctors have to be able to explain the rationale behind a decision. AI models use Blockchain technology as a friendly assistant for both patients and doctors to communicate with them during pre-surgery, surgery, and post-surgery (Le Nguyen and Do 2019). Research on the potential for artificial intelligence in healthcare discusses many instances in which AI can perform healthcare tasks as well or better than humans (Davenport&Kalakota, 2019). The satisfactory progress of AI tools in healthcare can be done for everyone by introducing a concerted effort among all those involved. It is thus time to also consider the opinion of patients and, together, address the remaining questions, such as that of responsibility (Reddy, 2020; Laï, Brian, & Mamzer, 2020)

There is a need for clinically validated and appropriately regulated AI systems that can benefit and are safe (Kelly et al., 2019; Wang, Kung, & Byrd, 2018). There are blockades to the espousal of artificial intelligence in the healthcare industry (Assadullah, 2019; Fish,2020) the technical challenge is to find solutions that address these ethical, legal, and societal issues. an effective framework of laws to govern privacy and data integrity, while dealing with issues of cultural acceptance, informed consent, liability, and explaining ability is needed in Artificial Intelligence in the Healthcare Industry (Yesha & Gangopadhyay, 2017). Models for customized hazard evaluations ought to be all around adjusted and productive, and powerful refreshing conventions ought to be executed. Cost, hazard, and vulnerability ought to be characterized for all potential applications (Ellahham, Ellahham & Simsekler, 2019.). The researcher expounded on the Strategies for the security of AI and ML in medical care that are advancing and are not yet completely created. Frameworks and applications with significant and ostensible security ought to be taken care of with a necessary convention. Models for customized risk evaluations should be very aligned and proficient, and compelling, refreshing conventions should be executed. Cost, hazard, and vulnerability ought to be characterized for all potential applications (Assadullah, 2019). Further Joyia et al., 2017) wrote about the future challenges of the internet of medical things in terms of medical services in healthcare and its contribution to the healthcare domain. IoMT enables the doctors as well as hospital staff to work more precisely and aggressively with less energy and intelligence. Hence recent efforts focus on IoMT integration frameworks (Rghioui and Oumnad, 2018; Gatouillat et al., 2018) like the Robust IoT-based nursing care support system which is a digital integration platform Chiang, Hsu, and Yeh, 2018). Similarly, Islam et al., (2015) proposed an intelligent model to decrease the risk of security and discusses the advancement of technology in the domain of IoT in the context of medical things, and also proposed e-health with IoT policies.

Jackson et al., (2003) dealt with the demonstrating procedures of IoMT-devices and summed up that the mix of devices is to a great extent concentrated according to a systems administration viewpoint. The IoMT comprises arranged associated clinical devices, unwavering quality, wellbeing, and security of organized network-connected devices. Alansari et al. (2018) in their work have distinguished different users of IoT in healthcare systems, as well as its function inclinations for the ongoing improvements in the domain of IoMT security. Azana et al., (2020) quoted that advanced technologies like blockchain can be used to minimize security threats to systems as well as humans. Health services, as well as commercial interactions by the government, can be improved with IoT (Chiuchisan, Costin, and Geman, 2014; Hossain, Muhammad, & Alamri, 2017). Dimitrov (2016) found that IoT is titivating healthcare services. Health requirements are now managed using IoT. There are security challenges and privacy concerns of IoMT(Zheng et al., 2020) like security-related issues because of the use of IoT-based healthcare application sensors (Nanayakkara, 2019) but blockchain technology can enhance security and guard the privacy of the IoMTsystem (Sun, 2019).

The review suggests AI approaches elicit medical and non-medical data in several categories and reconcile and incorporate information around communities with proof regarding the epidemiology and management of non-communicable conditions, Shaban-Nejad, Michalowski, & Buckeridge, (2020). Also according to the Mc Kinsey & Company report IoMT will host the economy with a manifold increase in its investments as it allows healthcare organizations to carry out this humongous feat relatively easily. The doctors can get access to the files quite readily without any problem (Ch. Venkateswarlu et al., 2016) but Venkatesh, (2019) brought about the way that the development of IoMT shows up when medical care delivery is by all accounts progressively costly. However, the ultimate goal for the usage of these technologies in this aspect is that the patients receive their treatment at the right time and at the right cost (Fischer & Lam, 2016). Further, the review also suggests In low-to-middle-income countries (LMICs), some of the challenges of integrating AI into healthcare systems relate to the hurdles of scaling digital health technologies(As per www.usaid.gov. 2018). This creates a barrier for AI tools for population health to scale at a national level. The reason for strengthened grounds for IoMT and AI in healthcare is the turmoil caused because of COVID-19 which acted as a Pivot for digital health to leap.

5. Objective

To analyze the factors of adoption of Artificial Intelligence (AI) and the Internet of Medical Things (IoMT) amongst healthcare workers.

6. Research methodology

A cross-sectional descriptive study was done wherein healthcare workers acted as the population. Using nonprobability purposive sampling a sample of 350 healthcare workers was considered for the study. Self-designed questionnaires on the challenges of Artificial Intelligence (AI) and Internet of Medical Things (IoMT) adoption in the Indian healthcare ecosystem were emailed to respondents between July 2020 to April 2021 including doctors and other healthcare staff was emailed as well as responses were taken by visiting the hospitals and clinics personally. In the end, the researcher was able to get three hundred filled questionnaires. Responses have been solicited on a Likerttype scale from 1 to 5, where 1 stands for minimum agreement and 5 stands for maximum agreement. A reliability test has been applied to check the reliability of the questionnaires with the help of Cronbach's Alpha. Exploratory Factor analysis has been applied to find out the factors associated with challenges of Artificial Intelligence (AI) and Internet of Medical Things (IoMT) adoption in the Indian healthcare ecosystem, separately for doctors and other healthcare medical staff of hospitals.

7. Factors affecting the adoption of artificial intelligence

Exploratory factor analysis is applied to know the factors indicating challenges in the adoption of Artificial intelligence Initially , a reliability test to check the reliability of questionnaires on the challenges of Artificial Intelligence (AI) was applied (table 1).

Table 1: Reliability statistics

Variables	Cronbach's _Alpha	No. of Items
AI (Medical Staff)	.777	8
IoMT (Medical Staff)	.856	8

The result is in line with the finding of Normally (1978) recommended that instruments used in basic research have a reliability of about 0.7 or better, therefore, all the items in the questionnaire are highly reliable.

Then the KMO test was applied (table 2) to check the normal distribution and sample adequacy whereas the Barlett test has been applied to check whether the responses matrix is the identity matrix and to find out whether the data is suitable for factor analysis not.

Table 2: Sample adequacy

Variables	No. of responses	KMO Value	Chi-square and Sig Level
AI (Medical Staff)	150	.776	280.036 @.000
IoMT (Medical Staff)	150	.889	425.539 @ .000

Table 2 shows data is good for applying exploratory factor Analysis.

Further two factors emerged indicating the challenges in adopting Artificial Intelligence (Table 3).

Table 3: Factors for challenges in adopting Artificial Intelligence

Variables	Factor 1	Factor 2	Cumulative Variance
challenges in adopting Artificial Intelligence	absence of a regulatory framework	unexplained return on investment in absence of research with low funding	54.079%

namely the absence of a regulatory framework and secondly unexplained return on investment in absence of research with low funding. These two factors explained a cumulative variance of 54.079 percent.

Factors affecting in adoption internet of medical things

Only one component namely the Internet of Medical Things was extracted in EFA performed to know the factors underlying challenges in the adoption of IoMT in medical staff. Huge Data and Operational Mediocrity with all-time processing requirements emerged as a challenge in the adoption of IoMT.

8. Study findings

The objective of the study was to find out challenges in the adoption of Artificial Intelligence (AI) and the Internet of Medical Things (IOMT) amongst healthcare workers as there is an evolving role of Artificial intelligence (AI) and the Internet of Medical Things (IOMT) due to market forces, growing millennial population, and technology adoption and patients are more aware than ever of their healthcare needs (KILIÇ, 2016). There is a major role of Doctors and medical staff in adopting these technologies and making fuller utilization (Parlakkılıç 2019). However, the study shows various challenges faced by Healthcare staff in adopting these technologies which include the non-existence of any healthcare regulatory body, unaffordability, and Low funding & returns. Further, there are other technology-based Adoption Challenges in terms of IoMT, like not being technically updated in understanding and interpreting the data obtained from

IoMT use. The research conducted showed that the efforts needed are from both healthcare workers as well as from the government to use this knowledge regarding challenges and provide the required legitimate preparation in form of training and better coordination among the healthcare workforce & arrangement (Oborn, 2008) in the organization to acknowledge productivity gains. These technologies can empower the health staff to take care of their job even more absolutely and effectively provided attention is paid to the factors giving challenges in the adoption of AI and IoMT.

9. Implications

The challenges found in the adoption of AI and IoMT in the research will help in understanding the improvements required in healthcare delivery making the healthcare system digitally ready for any such crises. There are other opportunities like starting new technology ventures, healthcare centers, and coming up with a public-private partnership (PPP) if the challenges identified are met. The study can be conducted even among the patients to know about their knowledge as well as perception about challenges in the adoption of AI and IoMT in the Healthcare System. The challenges further can be classified based on demographic factors such as age and education. The challenge for regulatory Framework relates to government policymaking and Low funding and Returns have implications for the investment needed in the sector which can be through government funding or the PPP model. Further,The adoption challenges in AI and IoMT need the involvement and training of healthcare workers

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Precise diagnosis of alzheimer's disease using recursive feature elimination method

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Abstract

One of the prevalent diseases that the elderly tend to have patients has been Alzheimer's disease (AD). It is a neurological disease where the brain cells start to deteriorate. As the disease progresses it eventually leads to the death of the brain cells. Death in brain cells results in various problems like memory loss change in behavior patterns and many more. The most challenging problem has been in predicting an early diagnosis of AD in patients. The importance of the disease is that it is detected early. If early detection is done, the death of brain cells can be reduced. The disease is predicted based on the various features of the patient. Feature selection has been one of the important steps in predicting the disease. This paper takes the OASIS data set and implements the different algorithms and proposes a model. The proposed model identifies the salient feature by recursively considering smaller and smaller sets of the features. The classification has been done for evaluating the feature selection. The result has been compared before the feature selection method and after the feature selection method. The performance metrics show improved scores after applying the feature section concept.

Keywords: Alzheimer, early diagnosis, feature selection, recursive feature elimination (RFE).

1. Introduction

Alzheimer's has been a neurodegenerative disease that mostly occurs in elderly people. Neurodegenerative, is a continuous worsening of the neurons, this affects the competence of the central nervous in a very intense and progressive manner (Scatena et al, 2007). AD is one of the prevalent neurodegenerative disorders (Small and D. H., 2005) and it is a cureless disease and the only treatment is to slow down its progression (Unay et al, 2010). The disease mainly affects the aged 60 to 65. A person at this age is at a high risk of being vulnerable to AD (Cummings et al, 2014). The disease grows progressively from a Cognitively Normal (CN) person to AD through Mild Cognitive Impairment (MCI) (Matsuda H, 2007), (Mosconi L et al. 2008). An Early Diagnosis (ED) of the disease would be helpful so that its progression can be reduced.

Feature selection is an important task in machine learning. If the dataset is processed without feature selection means then the accuracy of the prediction will be reduced, and the processing time will be increased so to avoid these issues the feature selection will be the best.

The diagnosis of the disease is done on studying the brain images or the Magnetic Resonance Imaging (MRI) of the brain. Along with MRI, some doctors use the s-MRI and resting-state functional magnetic resonance imaging (rs-fMRI) also. Both these have been used as the common method to analyze the changes, activities in the brain (Jun Jie Ng et al, 2016). Thus, the MRI serves as input using which AD is being diagnosed. The MRI of a patient has many features like gray matter densities, cortical thickness. The features related to diagnose and AD, needs to be retrieved from the MRI. When the correct features are selected, it helps in the correct diagnosis. The feature selection greatly affects or influences the classification performance and hence acts as the first step towards the prediction.

To have higher prediction accuracy the feature selection process needs to be done. The importance of feature selection process can be stated as to

- It decreases the training time of the machine learning algorithm.
- It increases the model accuracy as it uses the right subset
- It minimizes over fitting

Hence, the feature selection step becomes crucial. To perform the feature selection process a number of algorithms and techniques have been used. Feature selection is the process of selecting a subset from the original input data; also use these features as input to next step. The feature selection models have been classified to be of three methods:

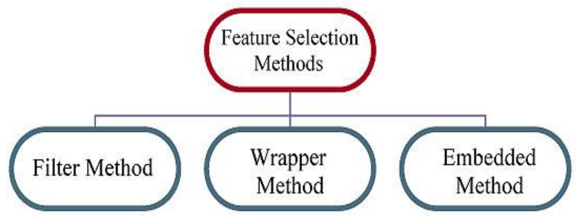

Fig. 1. Feature selection methods.

- Filter based
- Wrapper based
- Embedded

In the filter-based methods some metrics are specified as filters and based on those filters the features are selected. Some examples for this type of feature selection are Chi-squared test, Information gain. In the wrapper-based methods the feature selection is taken as a problem where a search technique is deployed. To perform the searching process algorithms like a best-first search are utilized. An example of these algorithms that use the wrapper method is the recursive feature elimination (RFE). Embedded methods work on the logic of learning about the features that contribute to the accuracy of the model that is being created. An example of an algorithm that uses the embedded methods is the regularization method.

Each of the above methods has its own advantage and disadvantages. Selecting and using the feature selection method depends on the problem and it also depends upon the existing data that the model has. ML(Machine Learning) algorithms in particular have been used in all the stages of AD prediction. Researchers have used these methods in the feature selection process to diagnose AD.

In this paper, the importance of the feature selection for an optimal prediction has been studied and analyzed. In the medical field the prediction of the disease is very important, which is done based on the symptoms. By constructing a machine learning model to predict the disease is done based on the features presented. Thus, the features play a vital role in the prediction of the disease. Appropriate selection of the features needs to be done for obtaining an optimal result. The detection of the Alzheimer disease is done based on the features available. For the study as carried out in this paper, OASIS dataset has been considered for the AD prediction. The different features of the disease are listed out and the feature selection is being done. Identifying the best feature has been one of the major tasks in predicting the disease. From the literature it shows that many of the previous works does not involve feature selection. Using the machine learning techniques, the feature selection is being done and the best feature has been identified and implemented.

The feature selection is necessary for selecting the required attributes for the prediction. It will remove the unwanted and the less priority attributes from the dataset using various feature selection techniques. It will use the attributes and the features effectively and efficiently for good prediction. If the attributes are not selected properly, the prediction of the disease will not be accurate. The feature selection will train the machine learning model very quickly also the over-fitting problem is reduced.

Outlines of the contributions are:

- Selecting the feature selection method.
- Constructing the feature selection model using machine learning.
- Select the attributes using the various feature selection methods for the prediction.
- Train the model and test the model.
- Evaluate the results.
- Comparing the results to other models.

- Analyzing the performance of the proposed model.

The proposed model in the paper uses the wrapper method. The paper is structured as Section 2 explains the related work, Section 3 describes the dataset, the design and working of the proposed model, the analysis is presented in section 4 and Section 5 explains the discussion with the future work and section 6 describes the conclusion.

2. Related works

Feature selection has been a vital step in building a machine learning model. To improve the accuracy of the predictive model, it is required to reduce the count of input variables or the features. This also reduces the computational cost of building a model. Researchers working on the prediction of AD, have used feature selection on two inputs, That are used in building the prediction model. Feature selection has been used on MRI and on the dataset. The proposed model presented in this paper takes the dataset and performs the feature selection on it.

There are many data sets that are available online, where all the details pertaining to an AD are stored. Some of the most used data sets are:

- The Alzheimer's Disease Neuroimaging Initiative (ADNI).
- Open Access Series of Imaging Studies (OASIS)

The ADNI data set is a longitudinal multicenter study that was created to develop clinical, imaging, genetic, and biochemical biomarkers. These were used for the early identification and diagnosis of Alzheimer's disease (AD). The data set includes participants who were recruited across North America during the stage of the study, and these participants had decided to complete diversity of imaging and medical assessments. Once the participants registered with ADNI, they were followed and reassessed over time. This is being done so as to track the pathology of the disease in the course of its progress. OASIS data set aims to provide neuroimaging datasets to the scientific and the research community. This helps in future discoveries. Many researchers have taken these two data sets and used them for building feature selection models that can be used in predicting AD. In detecting AD, the uses of computer technology have been used in vast numbers.

(Hinrichs et al, 2011) have made the ADNI data set, they used 48 AD patients and 66 Normal Controls (NC) for the diagnosis of AD, and they got an accuracy of 87.60% with the help of two image inputs of Positron emission tomography (PET) and MRI. The authors also achieved the result of 92.40% using the modalities of PET, MRI, Cerebro Spinal Fluid CSF, APOE, and cognitive values. In the model proposed by (Gray et al, 2013), they had used 37 AD patients, 75 MCI patients, and 35 NC for classify the AD and MCI patients. They used four modalities of PET, CSF, MRI, and genetics. With their model, they achieved an accuracy of 89.00% for AD classification and had an accuracy of 74.60% for MCI classification.

(Zhang et al, 2011) have proposed a model that used the same ADNI dataset and got an accuracy of 90.60% for the classification of AD, they have used the MRI and PET. They were able to achieve an accuracy of 93.20% for the classification of AD by using three inputs the MRI, the PET, and the CSF. (Feng Liu et al, 2014) have proposed a model that gave a result of 94.37% and the ROC curve (AUC) of 0.9724 in detecting AD. They also achieved an accuracy of 78.80% and an AUC of 0.8284 in identifying.

(Trambaiolli et al, 2017) have developed a model that used the Filtered Subset Evaluator technique and were able to achieve the best performance improvement for the patient is 91.18% of accuracy and on an epoch basis is 85.29±21.62%. They first removed 8.76±1.12% of the original features. Riedel et al., have proposed a model where AD features were selected from the different neuroimaging modalities. These were used to create more useful measures, and these features included mean gray matter densities, subcortical, cortical thickness, and cerebral amyloid-b accumulation in regions of interest (ROIs). (Lecun et al, 2015) have proposed a model and used the Deep learning (DL) method of convolutional neural networks (CNN), to build models. The authors have proved that this method of using DL has been shown to outperform the other existing machine learning methods. Thus, many feature selection models have been developed using different approaches. The model proposed in this paper uses the Recursive Feature Elimination method. (Sivakani et al, 2020) have generated the missing values using the algorithms EM, KNN, and RF algorithms. (Sivakani et al, 2020) have done the feature selection using the best-first search algorithm and cfssubsetevalu evaluator.

(Wiharto et al, 2022) have done a study for the diagnosis of heart disease using a feature selection method developed with the genetic algorithm and support vector machine. Out of 54 features, only 5 features are selected and produced 87% accuracy. (Z. D. Akşehir et al, 2022) have introduced a new rule-based labeling algorithm and a feature selection method for the prediction of CNN model performance. (Chen et al, 2020) have specified four reasons for showing the importance of feature selection. The feature selection reduces the parameters, decreases the model building time enhances the generalization, and reduces the dimensionality. The evaluation has been done using the random forest, support vector machines, K-Nearest neighbors, and Linear Discriminant Analysis. (Jianting Chen et al, 2021) have proposed a novel self-learning feature selection method using the wrapper method the improvement the accuracy of the machine learning model. The evaluation has been done using sixteen UCI repository datasets. (Lianxi Wang et al, 2021) explained the uses of the feature selection algorithm to increase the accuracy of the classification. The evaluation has been done using the UCI datasets. (Chu Y.M et al, 2020) studied hybrid nanoparticles for various mixtures and their applications. (F. Heydarpour et al, 2020) introduced a system of ordinary differential equations (ODE) to predict tumor growth. An artificial neural network has been applied to solve the problem in the ODE. (He Z. Y et al, 2022) presented a new fractional-order discrete-time susceptible-infected-recovered (SIR) epidemic model with vaccination to find the system's dynamics using the numeric value. The complexity of the system has been analyzed and verified. (Rahiminasab A et. al, 2020) introduced a model for choosing a cluster head for the energy prediction, using the attributes energy, mobility, distance and the length of data queues. (Fang Jin et. al, 2022) proposed a new system to prove the uniqueness of the result using the fixed point theory and the Picard technique.

The literature clearly shows the importance of feature selection in medical and other fields. So a model has been proposed to predict the disease with the feature selection. In this paper, the disease prediction has been made with various feature selection techniques and without applying feature selection techniques; then, the result has been compared and proved that the effect produced with the feature selection technique is the best. The proposed model has been compared with the model (Trambaiolli, L. R., et al, 2017) and shows the better accuracy.

3. Proposed model

AD has been one of the challenging diseases that have been very difficult to diagnose at an early stage. When a patient is being tested for the symptoms of the disease, a number of features are taken into account. Evaluating these features and diagnosing the disease based on these features has been a critical method. Using ML, a number of approaches are available to do the feature selection. The model proposed here uses the wrapper approach which is found to have certain advantages when compared to the other approaches. This section first presents the dataset used in the paper and then discusses the design of the proposed model. The dataset has been preprocessed and is subjected to feature selection. Various feature selection methods have been used and the result is compared to predict the best feature selection method. The RFE method will remove the least important attribute for the prediction. The features for the processing will be selected and a subset has been generated using the machine learning techniques. Based on the less importance of the attributes, it will eliminate and with the other attributes, the processing will be done for the best prediction.

3.1 Dataset

The dataset taken for the proposed model is the OASIS dataset. The recent dataset of OASIS has been the OASIS-3 which has displayed data for above than 1000 participants. All these participants were across several ongoing projects for 30 years. The partakers included 609 CN adults and 489 patients at several phases of cognitive decline, all the participants were aged from 42-95years. This dataset has the details such as patient ID, Gender, Dominant Hand, Age, Education detail, etc. These features are taken and the processing is done.

3.2 Design of the model

The feature that is used to train any machine learning model has a great impact on the performance of the model. A feature that is irrelevant or partially relevant can have a negative impact. The proposed model makes use of the RFE method that follows the wrapper approach. RFE is based on the scheme to repeatedly construct a model and then the best or worst performing feature is chosen. The chosen feature is set aside and the process is repeated again taking the rest of the features. This process is functionally applied until all the features in the dataset are taken out. All the features are then ranked according to when they were eliminated. This technique can be called a greedy optimization problem that can be used for finding the best performing subset of features. The process of RFE is given in Fig. 2.

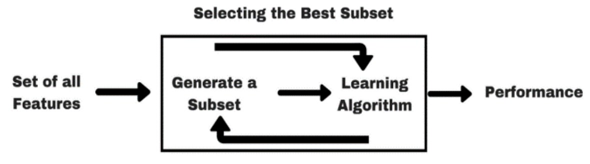

Fig. 2. Recursive feature elimination

The various features present in the dataset are tabulated in the Table 1.

Table 1. Data description

S.No	Attribute_ Fields	Description
1	Subject ID	Subject Identification number
2	MRI ID	MRI Identification number
3	Group	Group of the patient
4	Visit	Visit of the patient
5	MR Delay	MR delay of the visit
6	M/F	Gender
7	Hand	Mental State test
8	Age	Patient's age
9	EDUC	Education status
10	SES	Social economic Status
11	MMSE	Mini Mental State Examination
12	CDR	Clinical Dementia Rating
13	eTIV	Estimated Total Intracranial Volume
14	nWBV	Normalize Whole Brain Volume
15	ASF	Atlas Scaling Factor

4. Result and discussion

The data set has been used in various algorithms and the result has been evaluated. The OASIS dataset has been used for the evaluation of the feature selection algorithms. The result has been analyzed in two-step processes; first, the dataset has been preprocessed and the classification has been done without applying feature selection methods and in the second step the classification of the dataset has been done with the feature selection method. Finally, the result has been compared for finding the best feature selection method. In this regard, the CFS subset attributes selection, classifier attribute selection, correlation attribute, and relief attribute selection methods have been used for the feature selection and for the evaluation these methods Naïve Bayes, Logistic Regression, SVM, Bagging, Logitboost, Multiclass, JRip, J48, Random Forest, REP Tree classifiers has been used to find the best feature selection method.

4.1 CFS subset attributes selection

CFS is the Correlation-based feature selection; this algorithm selects the attributes which have a high correlation with the classification task. The equation used in the subset evaluation is given below:

$$r_{zc} = \frac{k\overline{r_{zi}}}{\sqrt{k + k(k-1)\overline{r_{ii}}}}, \quad (1)$$

Where, r_{zc} is the correlation of the attributes, k is the number of attributes, $\overline{r_{zi}}$ is the average of the correlations $\overline{r_{ii}}$ is the average inter-correlation among the attributes.

We have applied CfsSubset algorithm to evaluate the subsets. The search methods applied for finding the best attributes are best first search method, greedy search method. The direction of the attribute search taken place in forward direction. Total we have 373 instances and 15 attributes.

When we are applying the CfsSubset algorithm along with the best first search method the evaluated subsets are 104 and the accuracy of the best attribute search is 0.98 and the selected attributes are 1,4,12,13,14. Totally the selected attributes are Subject ID, Visit, CDR, eTIV, nWBV

When we are applying the CfsSubset algorithm along with the greedy search method the evaluated subsets are 104 and the accuracy of the best attribute search is 0.98 and the selected attributes are 1,4,12,13,14. Totally the selected attributes are Subject ID, Visit, CDR, eTIV, nWBV. Both the methods selected the same attributes as the best.

4.2 Classifier attribute selection

The classifier attributes algorithm works based on the prediction concept for selecting the best subset. The search method applied with the evaluator is the ranking method. Rank will be generated for each attribute; the rank will be generated between -1 and +1. The ranking method is applied along with this algorithm to choose the best attribute. For each attribute, the rank is generated, and based on the rank the best attribute is selected. The wrapper and RMSE methods are used for subset evaluation. The accuracy is 5 and the Selected attributes are 14,4,5,3,13,2,6,7,8,9,12,11,10,1; total 14 out of the 15 attributes. The rank generated for each attribute is given below:

Table 2. Rank generated by the classifier attribute selection algorithm

Sl. No.	Rank	Attribute number	Attribute Name
1	0	14	nWBV
2	0	4	Visit
3	0	5	MR Delay
4	0	3	Group
5	0	13	eTIV
6	0	2	MRI ID
7	0	6	M/F
8	0	7	Hand
9	0	8	Age
10	0	9	EDUC
11	0	12	CDR
12	0	11	MMSE
13	0	10	SES
14	0	1	Subject ID

4.3 Correlation attributes selection

The correlation attribute is a prediction of the best attribute based on the linear relationship between the attributes. Along with the correlation attribute, the ranking search method is applied to find the best attributes based on the rank generated by this algorithm. The selected attributes are 6,10,14,1,2,11,3,7,12,8,4,5,9,13 and totally 14 attributes are selected. The accuracy is 0.138. The rank generated for each attribute is given below:

Table 3. Rank generated by the correlation attributes selection algorithm

Sl. No.	Rank	Attribute number	Attribute Name
1	0.5616	6	M/F
2	0.2467	10	SES
3	0.2135	14	nWBV
4	0.0663	1	Subject ID
5	0.041	2	MRI ID
6	0.0395	11	MMSE
7	0.0239	3	Group
8	0	7	Hand
9	-0.0293	12	CDR
10	-0.0351	8	Age
11	-0.1204	4	Visit
12	-0.1235	5	MR Delay
13	-0.2418	9	EDUC
14	-0.9889	13	eTIV

4.4 Relief attributes selection

The relief attribute algorithm predicts the best attributes based on the weight allocated for each attribute. Along with the Relief algorithm the ranking search method is applied to select the best attributes. The selected attributes are 1,13,9,10,14,8,11,7,2,6,3,12,5,4; totally 14 attributes are selected as the best attributes. The accuracy is 0.138. The ranks generated for each attribute are given below:

Table 4. Rank generated by the relief attribute selection algorithm

Sl. No.	Rank	Attribute number	Attribute Name
1	0.15901	1	Subject ID
2	0.10424	13	eTIV
3	0.01446	9	EDUC
4	0.01144	10	SES
5	0.00874	14	nWBV
6	0.00453	8	Age
7	0.00392	11	MMSE
8	0	7	Hand
9	0.0000	2	MRI ID
10	-0.00106	6	M/F
11	-0.00354	3	Group
12	-0.0052	12	CDR
13	-0.0510	5	MR Delay
14	-0.0549	4	Visit

Representation of number of attributes selected is given in the below graph.

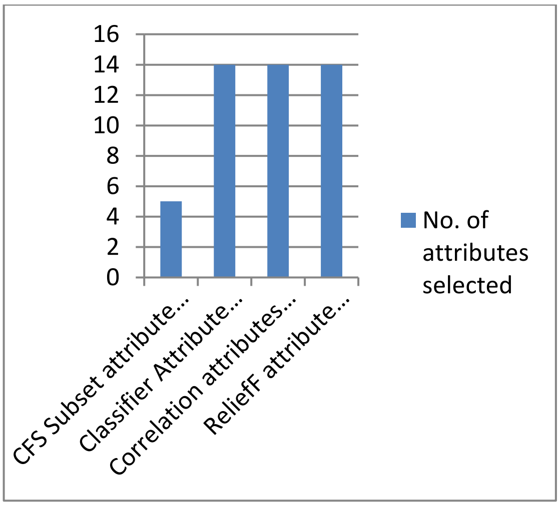

Fig. 3 Representation of the attributes selected

This Fig. 3 shows the representation of the attributes selected by the algorithms. From the above graph we can identify that the CFS subset attribute selection algorithm has been selected 5 attributes and the other algorithms has selected 14 attributes. So, for a good classification or a prediction we need these 14 attributes from this dataset.

4.5. Classification and comparison of the classifier before and after applying the feature selection concept

The classification has been done for evaluating the performance of the classifiers and comparison has been done before applying the feature selection and after applying the feature selection. The classifiers considered for the evaluation are Naïve Bayes, Logistic Regression, SVM, Bagging, Logitboost, Multiclass, JRip, J48, Random Forest, REP Tree classifiers.

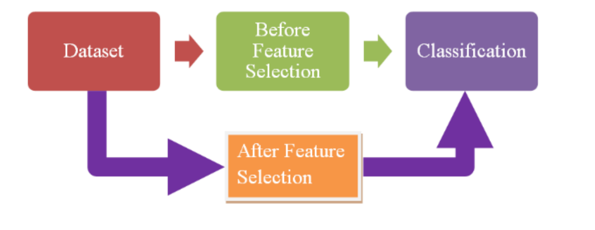

Fig. 4. Representation of the attributes selected

Fig. 4, describes that the dataset has been classified before and after feature selection. Before applying feature selection the score is less and after the feature selection the result has been improved.

Table 5. Performance of Naïve Bayes Classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	92.7	93.29
2	Precision	0.923	0.939
3	Recall	0.928	0.933
4	F-Measure	0.924	0.930
5	ROC	0.981	0.991

Table 5, shows the metrics comparison for the Naïve Bayes classifier before and after the feature selection.

Table 6. Performance of logistic regression classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	98.3	98.41
2	Precision	0.984	0.995
3	Recall	0.984	0.994
4	F-Measure	0.984	0.994
5	ROC	0.955	0.995

Table 6, shows the metrics comparison for the Logistic Regression classifier before and after the feature selection.

Table 7. Performance of SVM classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	98.6	98.75
2	Precision	0.987	0.987
3	Recall	0.987	0.997
4	F-Measure	0.986	0.986
5	ROC	0.982	0.991

Table 7, shows the metrics comparison for the SVM classifier before and after the feature selection.

Table 8. Performance of bagging classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	97.58	97.68
2	Precision	0.968	0.977
3	Recall	0.976	0.976
4	F-Measure	0.976	0.98
5	ROC	0.989	0.999

Table 8, shows the metrics comparison for the Bagging classifier before and after the feature selection.

Table 9. Performance of logitboost classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	91.68	91.78
2	Precision	0.916	0.917
3	Recall	0.917	0.927
4	F-Measure	0.896	0.896
5	ROC	0.943	0.953

Table 9, shows the metrics comparison for the Logitboost classifier before and after the feature selection.

Table 10. Performance of multiclass classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	98.39	98.65
2	Precision	0.984	0.987
3	Recall	0.984	0.997
4	F-Measure	0.984	0.987
5	ROC	0.989	0.999

Table 10, shows the metrics comparison for the Multi classifier before and after the feature selection.

Table 11. Performance of JRip classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	91.15	93.29
2	Precision	0.901	0.928
3	Recall	0.912	0.933
4	F-Measure	0.904	0.926
5	ROC	0.921	0.943

Table 11, shows the metrics comparison for the JRip classifier before and after the feature selection.

Table 12. Performance of J48 classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	87.39	87.45
2	Precision	0.805	0.815
3	Recall	0.874	0.894
4	F-Measure	0.838	0.868
5	ROC	0.868	0.878

Table 12, shows the metrics comparison for the J48 classifier before and after the feature selection.

Table 13. Performance of random forest classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	95.97	96.24
2	Precision	0.962	0.974
3	Recall	0.960	0.962
4	F-Measure	0.955	0.958
5	ROC	1.00	1.00

Table 13, shows the metrics comparison for the Random Forest classifier before and after the feature selection.

Table 14. Performance of REP classifier

Sl. No.	Parameter Metrics	Result before feature selection	Result after Feature selection
1	Correctly Classified	97.85	97.95
2	Precision	0.979	0.989
3	Recall	0.979	0.98
4	F-Measure	0.978	0.988
5	ROC	0.989	0.999

Table 14, shows the metrics comparison for the REP classifier before and after the feature selection.

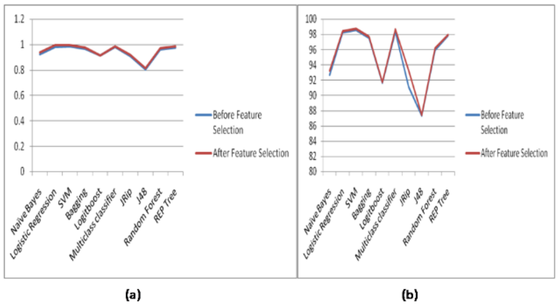

Fig. 4(a) & 4(b). Metrics comparison for precision and accuracy of classifiers

Figure 4(a) shows the comparison of precision values before and after feature selection for the classifiers. 4(b) shows the comparison of accuracy values before and after feature selection for the classifiers.

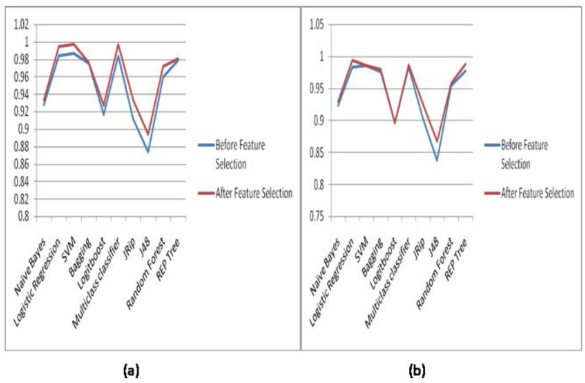

Fig. 5(a) & 5(b). Metrics comparison for recall and f-measure of classifiers

Fig. 5(a) shows the comparison of Recall values before and after feature selection for the classifiers.

5(b) shows the comparison of F-Measure values before and after feature selection for the classifiers.

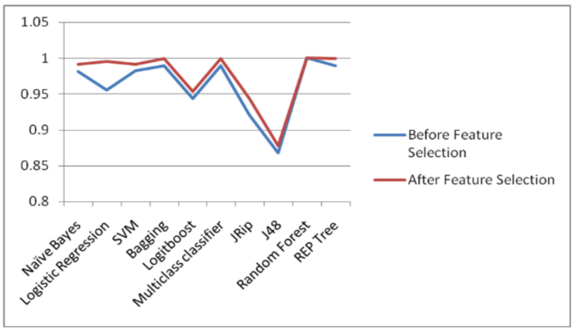

Fig. 6. Metrics comparison for ROC of classifiers

Fig.6, shows the comparison of ROC values before and after feature selection for the classifiers.

From the comparison, it has been analyzed that the performance for all the classifiers given improved scores after applying the feature selection.

5. Conclusion and Future Enhancement

This paper discusses various feature selection algorithms for selecting the best attributes for the classification or prediction. The best attributes can be selected by using the feature selection method. CFS Subset attributes selection, Classifier Attribute Selection, Correlation attributes selection, and Relief attribute selection are the algorithms applied to the oasis dataset; in the dataset, there are 15 attributes, and among those attributes, the best attributes selected are 14 attributes. CFS Subset attributes selection algorithm selected only 5 attributes, and the other algorithms selected 14 attributes so it concluded that for the classification of this dataset 14 attributes are best. Also, the classification has been done to evaluate the performance of the feature selection process. The evaluation metrics considered are accuracy, Recall, F-Measure, and ROC. All the performance metrics show better results after applying the feature selection. The results have been compared without feature selection and with the feature selection process; all the evaluation metrics show the better result with the feature selection process. Also, the proposed model has been compared with the result of the previous model and shows a better result. The previous model has 91.18%, and this proposed model gives the best result of 98.7%. So it is concluded for the best prediction, the feature selection should be done. In future work, we decided to focus on other feature selection algorithms.

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Detection of CAD using optimization approach with machine learning classification techniques

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Abstract

Coronary Artery Disease is one of the most serious ailments among cardiovascular disorders. High expenses of its' detection using conventional tools like angiography are the key concerns for patients. Supervised machine learning models for automatic classification of the Coronary Artery Diseases are highly accurate, optimal, and cost effective ways. Accuracy of machine learning techniques is dependent on amount and type of data used for training. A large amount of data generated in healthcare organizations help in assisting re-searchers in order to quickly and accurately diagnose the problem using machine learning techniques. Alt-hough, these techniques are effective in diagnosing coronary artery diseases, requires optimization for im-proving the accuracy. In this research, the researchers the authors propose an optimum machine learning based classification approach. They integrate Independent Component Analysis and Principal Component Analysis algorithms for feature extraction, and hybrid of Particle Swarm Optimization and Firefly Algorithm for feature optimization. The performance evaluation, and comparative analysis of the proposed approach and state-of-the-art techniques prove its' superiority.

Keywords: Cardiovascular Diseases, Machine Learning, Optimization Techniques, Coronary Artery Diseases.

1. Introduction

Coronary Artery Disease (CAD) is one of the most life threatening diseases. In this disease, Plaque, a waxy material, gets accumulated inside the coronary arteries as shown in figure 1. It hinders the primary function of arteries and decreases the blood and oxygen supply to the heart muscles. Blood clots can obstruct the flow of blood in the arteries, making it one of the deadliest illnesses. The heart muscles begin to deteriorate. It causes the arm discomfort, stomach ache, nausea, dizziness, tiredness, and sweating. The plaque might burst or harden over time and lead to a heart attack. This may cause death if care is not received immediately. CAD is responsible for more than 30% of all fatalities worldwide. Therefore, it is necessary to detect and cure it at an early stage. Health care therapy for the treatment of Plaque is a lengthy procedure that might takes many years. If CAD is identified at an early stage, the mortality rate can be reduced.

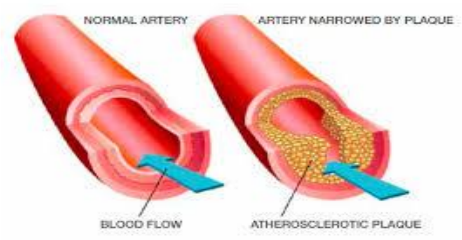


Figure 1. Artery types

The potential of Machine Learning (ML) techniques can be used for the identification of CAD. The growing volume of data may provide opportunities to employ ML techniques to discover important information, and to improve diagnosis accuracy (Latha, 2019).

Putting an effort in this domain, a system is developed for efficient prediction using ML techniques that learn from the previous data (Arora S., Agarwal M., Mongia S, 2021). These techniques are superior in accuracy, are inexpensive in computation, and adaptable to different datasets (Zipes, 2018). Also, ML techniques have the potential to identify the patterns in medical images (Nitesh Pradhan and Geeta Rani, 2020), categorise them into numerous categories (Rani.G and Oza, Da), recreate medical images without contorting its quality (N. Pradhan and V.S Dhaka, 2020), and improving the quality of image without losing more information (N.Kundu and G. Rani, Set). These techniques are capable in data analysis and making decisions according to the trends attainable in the dataset (G.Rani and Oza, 2021). Therefore, ML techniques can be easily accepted.

For the identification of coronary artery disorders, ML based classification approaches such as K Nearest Neighbour (S. Zhang, 2018), Decision Trees (M. Jaworski, 2018) Naive Bayes (C.-z. Gao, 2018) Support Vector Machine (H. Yan, 2018), and Artificial Neural Network (ANN) (X. Liu, 2017) have been employed. But, few studies focused on optimization and hybridization of optimization methods with ML based classification algorithms. These methods deliver excellent results and have been successfully used to predict CAD. Therefore, these methods must be prioritized. In this manuscript, the authors work on the above identified challenges, and propose an integration of optimization and ML based classification approaches for precisely detecting CAD. The paper's main contributions are the following:

1) To minimize redundancy by employing integration of Principal Component Analysis (PCA) and Independent Component Analysis (ICA) for Feature Extraction.

2) To improve accuracy of CAD detection using optimized ML technique.

3) To present a comparison of ML techniques without employing optimization techniques, and after employing ML techniques.

3) To identify best suitable classifier for CAD diseases among SVM, DT, RF, and ANN

Paper is structured as follows: Introduction in mentioned in section 1. Section 2 describes the similar research work which puts light on the several valuable researches done in the diagnosis of CAD. Section 3 covers the proposed methodology and algorithm employed to build the proposed solution. Section 4 discusses the result and discussion of the proposed work and section 5 presents the conclusion and future scope.

2. Related work

On medical datasets, different experiments are done with different classifiers and feature selection algorithms but very little researches have done on the classification of cardiovascular disease that shows good accuracy of classification (M. Fatima and M. Pasha, 2017). For example, the work proposed in reference (K. C. Tan, 2009) propose a hybrid of two ML algorithms SVM, and GA. They used WEKA and LIBSVM tools to analyse the results with 5 different datasets and achieved the accuracy of more than 75% for all 5 datasets. In reference (A. F. Otoom, 2015) SVM, Naïve Bayes, and functional algorithms reported the accuracy of 85.1%, 84.5%, and 84.5% respectively for detection of CAD using Cleveland dataset. Implementation is done in the WEKA tool. 7 best features were selected with the help of the best first selection algorithms.

In paper (G. Parthiban and S. K. Srivatsa, 2012) SVM and naïve bayes algorithms were used to diagnose cardiovascular disease in diabetic patients. WEKA tool was used to implement the algorithms. Data of 500 patients were collected from research Chennai institute. 142 patients had the disease and 358 patients do not. The accuracy of 74% was reported. Similarly, iIn paper (V. Chaurasia and S. Pal, 2014), data mining approaches were used to detect heart disease. 11 attributes were considered in the prediction from a list of 76 attributes. The accuracy of 84.35% was reported by J48, 82.31% by Naïve Bayes, and 85% by Bagging.

Further, in paper (K. Vembandasamy, 2015) datasets consists of 500 patients' records were collected from the Chennai diabetes research institute. Naïve Bayes algorithm is applied on this dataset and accuracy of 86% was reported. Now, In the paper (X. Liu, 2017) heart disease is detected with the help of a hybrid classification system of the ReliefF and Rough Set (RFRS) method. Accuracy of approximately 92.59% was reported. It is evident from the above discussion that a few works focused on optimizing the ML based classifiers for the detection of CAD. Moreover, a few works integrated the feature reduction, classification, and optimizing techniques for prediction of CAD at an early stage.

3. Proposed methodology

Hybridization of PSO and FA algorithms is employed for optimization objectives using decision trees, random forest, SVM, and ANN classification approaches in this proposed methodology section. The decision tree is widely used because of its hierarchical structure, which allows it to solve nonlinear complex problems. Random forest, on the other hand, works better on high-dimensional data and has a faster computation speed on training data than other algorithms, with less data pre-processing. The proposed model uses PCA and ICA for feature extraction, as well as hybridization of PSO and FA with classification approaches such as decision tree, artificial neural network, random forest, and support vector machine. PSO and FA optimization algorithms are used to select best combination of characteristics or the best solution out of a number of options. The proposed methodology is depicted in the figure 2.

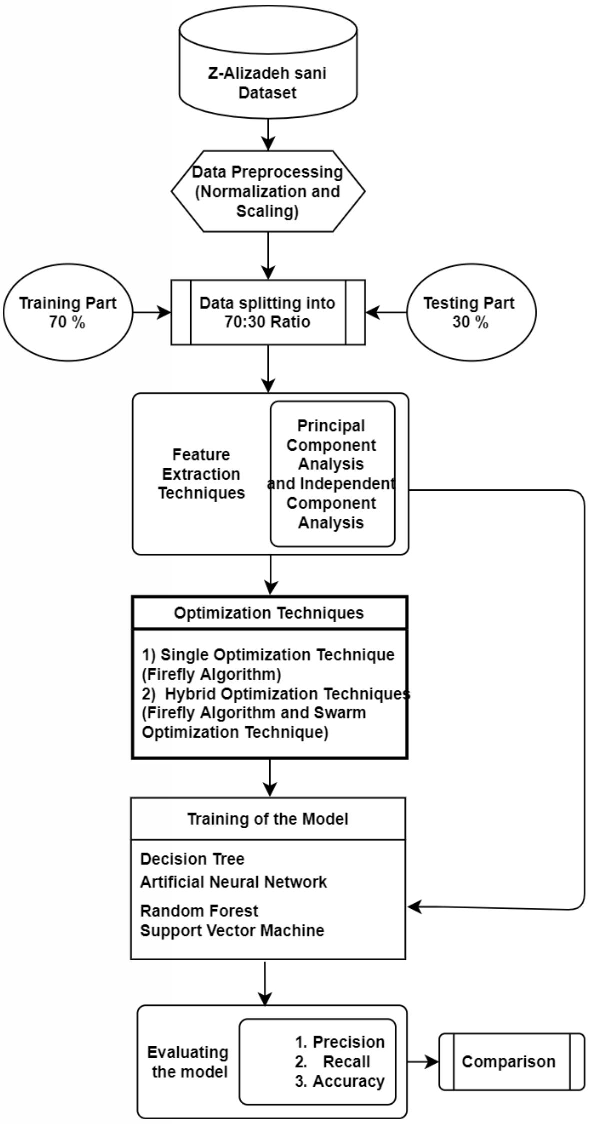


Figure 2: Proposed architecture

In the proposed approach, PCA and ICA are used as a feature extraction technique. Artificial Neural Network (ANN), random forest, SVM, and decision tree algorithms for classification. From the dataset, features are extracted and optimized with the help of PSO and FA for the improved results.

3.1 Dataset

Z Alizadeh Sani Dataset (Set, 2017) consists of records of 303 patients with 56 attributes. All features are divided into four parts demographic, symptom and examination, ECG, and laboratory and echo features. Patients are divided into two categories which are CAD patients or normal. This dataset consists of a large number of attributes and is free from missing values.

3.2 Data preprocessing

In this stage, data is homogenized in the domain of 0 and 1 using the min-max function. Data processing is done in order to make the proposed model machine friendly. Normalization and scaling is performed to convert the string into integers and also convert all the values in the same range.

3.3 Feature extraction

The availability of thousands of features in a dataset may cause inconsistencies. Thus, it is necessary to remove redundant data, and extract highly correlated features in order to improve the accuracy of the model. The complex structure of the dataset increases computation time and makes data processing slow. So, there is a need for feature extraction algorithms to get rid of these problems. PCA is the most widely used dimension reduction techniques. It is one of the that helps to identify correlations and patterns in a dataset so that it can be transformed into a new dataset that has significant low dimensions without loss of much information. Narrowing down a couple of variables from the original dataset. Various steps are involved here 1) Standardization of data: scaling of the data is done in such a manner that variables and their values lie within a similar range z=variable value-mean/standard deviation 2) Computing covariance matrix-it express the correlation between different variables in a dataset. It is necessary to remove the dependent feature because it contains biased and redundant information which reduces the performance of the proposed model. Covariance can be negative or positive. 3) Calculating the eigenvectors and eigenvalues-these are computed from the covariance matrix to determine principal components of the data set 4) Computing principal components-

Highest eigenvalue has the most significant feature and forms the first principal component. 5) Last step is to rearrange the original data with the final principal components which represent the maximum and most significant information of the dataset.

The second feature extraction process with the combination of machine learning used is the independent component analysis. ICA describes a reproductive model for the experimental multivariate records, which is usually a large samples dataset. In a machine learning model, the variables used as input are supposed to be linear combinations of some new suppressed variables. The suppressed variables are supposed nongaussian and commonly self-determining which are well known as the independent components based on the observed information. ICA has nearly correlated to PCA i.e. principal component analysis. ICA is a much extra controlling procedure, however, proficient in finding the essential parameters used for the feature extraction process. The information analyzed using the ICA process could originate from several application areas, including images, databases, financial methods, and psychometric dimensions. In many belongings, the dimensions are set of time series data where the blind source split-up is used to illustrate the defined problem.

3.4 Feature optimization

In feature optimization hybridization of swarm particle optimization and firefly nature-inspired algorithm is used for the selection of instances and to identify the best solution among different possible solutions for classification.

3.4.1 Firefly algorithm

Various assumptions of fireflies are the following like attraction towards each other, attraction is directly proportional to their brightness, in case of same brightness of two fireflies, they move randomly and from random walk new solutions are identified.

The steps of firefly algorithms are given below:

1) Initialization of parameters is done.

2) Population of n fireflies is generated.

3) Fitness value of each firefly is evaluated.

4) Condition is checked, accordingly position and intensity of light are updated.

5) Best solution is reported.

Firefly algorithm is widely used for its numerous advantages as compared to other optimization techniques. Those advantages are 1) Population is divided into several parts automatically 2) It deals with multi-model optimization 3) In solutions, there is high randomness.

3.4.2 Particle swarm optimization

Particle swarm optimization algorithm is inspired by the social behavior of birds flocking and solves hard complex problems. This algorithm is a population-based algorithm. Members of the population are called particles and the population is called a swarm. There are various advantages of PSO over other optimization techniques. PSO is applied on coronary artery diseases successfully and it has given fantabulous results. In PSO objective function tries to maximize or minimize the values which need to optimize. Various advantages of PSO are following. 1) It is very easy to implement and has very few parameters to work with 2) Higher chances of finding out the global optima 3) Takes a short time of computation. 4) Robust and converge fast.

The steps of the particle swarm optimization are the following:

1) Population and parameters are initialized.

2) The fitness value of each particle is evaluated and the best particle is chosen.

3) The velocity and position of every particle are calculated.

4) Find the current best (Gbest).

5) Update iteration t.

6) Output is Gbest.

3.5 Classification techniques

In the classification technique, data is divided into numerous categories or several classes. In the classification approach when the test data is applied and the training model gets loaded, the predictions will be made based on the supervised learning models and at that stage it can be noticed through the class labels that whether the person is having disease or not. The main objective of using these classification techniques is to find out the category/class of the new data belongs to. In the early prediction case it depends on the type of input and the processing done on the input based on the early prediction characteristics which can reduce the quantitative risks for the same. In the proposed approach main concentration is given to the end to end prediction.

3.5.1 Decision tree algorithm (DT)

Decision tree is one of the most popular algorithms used for classification. Based on the condition of the internal node, the tree is divided into different edges and the last decision is taken on that branch, which stops splitting more, and that will be the last decision of the classification process.

Advantage of Decision Tree approach:-

1) The decision tree generates easy and understandable rules.

2) With much computation, classification is performed in decision trees.

3) Continuous and categorical variables are easy handled by decision trees.

4) It gives a crystal clear idea about the prominent fields for the purpose to predict and classify.

3.5.2 Random forest (RF)

Random forest is one of the widest algorithms used in machine learning. Random forests are bagged decision trees, which are split on a features subsets basis. RF can manage categorical, binary, and numerical features. Very little pre-processing is required as there is no requirement for rescaling and transformation. There are various advantages of the Random forest classification technique over other classification techniques.

1) On high dimensions data, it works efficiently.

2) It can manage lots of inputs variables without deletion of variables.

3) It gives a clear idea about which variable is more valuable.

4) Most accurate learning algorithm.

5) Parallelizable (Process can be split into multiple machines to run).

3.5.3 Support vector machine (SVM)

SVM is one of the significant supervised learning systems, used for sorting and regression complications. But, mainly, it is used for ordering difficulties in data science and machine learning concepts. The objective of this supervised process is to generate the superlative decision boundary that can separate n-dimensional space into modules that are called class labels so that the efficient prediction will be made on the new dataset in the real-world scenario. This top decision borderline is known as a hyperplane. SVM elects the extreme data vectors that help in generating the decision boundary. These extreme points are well known by support vectors as shown in figure 3.

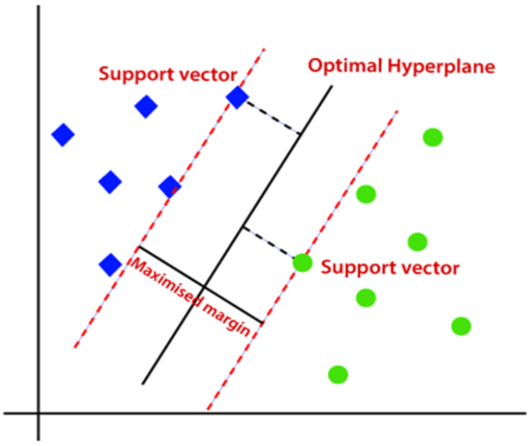


Figure 3. Artificial neural network

The working of ANN is like the structure of a human understanding. Comparable to the human mind that has processing elements called neurons interrelated to the other neurons in the network, artificial neural networks also have neurons that in a similar way the ANN structure are interconnected nodes to other nodes organized in the form of layers. ANN structures are arranged as per the sequence of the layers. There are mainly three layers in ANN i.e. Input layer, Hidden Layer, and Output Layer as shown in figure 4. It regulates weighted input passed to an activation utility to produce the relationships. The activation function decides the life of the node in the ANN that whether it should be accepted or not between the layers. There are unique activation functions accessible that can be functional on the type of requirement that needs to be implemented.

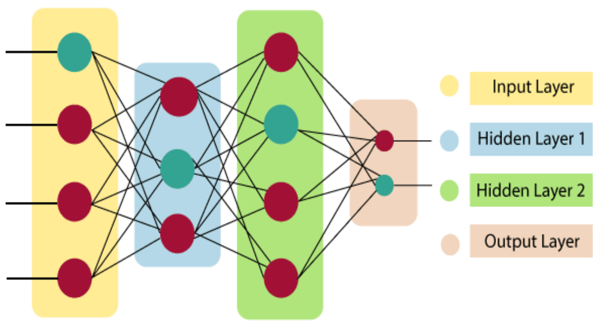


Figure 4: Typical structure of an N

3.6 Classification task

In the classification technique, data is divided into numerous categories or several classes. In the classification approach when the test data is applied and the training model gets loaded, the predictions will be made based on the supervised learning models and at that

stage it can be noticed through the class labels that whether the person is having disease or not. The main objective of using these classification techniques is to find out the category/class of the new data belongs to. In the early prediction case it depends on the type of input and the processing done on the input based on the early

prediction characteristics which can reduce the quantitative risks for the same. In the proposed approach main concentration is given to the end to end prediction.

3.7 Proposed algorithm

Step 1: Input Records such that R = R1, R2… RN as data and perform the framing of the data to process in a structured format.

Step 2: Scaling of the Records.

Step 3: Extract the feature vector F(x) & transform it to produce the covariance.

Step 4: If PCA performs Eigenvector extraction to extract meaningful understandings for the transformation to map the data and generate a new vector space.

If ICA Perform transformations on the data to get the independent Gaussian components.

Step 5: Perform instance selection using optimization methods firefly algorithm and particle swarm optimization for the dimensionality reduction process.

Step 6: Generate splitting of the data into different ratios 70% is training data & 30% is the test unknown data.

Step 7: Generate the Ensemble Learning.

Step 8: Upload unknown samples.

Step 9: Call the trained model and implement classification on Test dataset.

Step 10: Estimate the performance of the model in terms of Precision, Recall, and Accuracy.

4. Experiments and results

The proposed work is implemented in python using the Pycharm editor by creating the virtual environment. A virtual environment is created to reduce the dependencies among the different libraries installed for the smooth functioning of the implementation. Pycharm is widely used to perform complex technical computations and is handier to run the simulation environment.

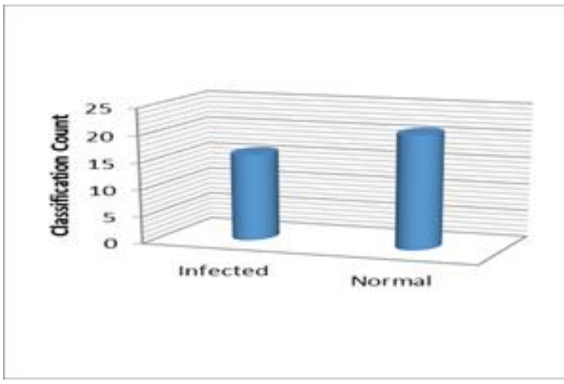


Figure 5: Classification

Fig 5. Shows the classification counts from the test data and is unknown data and performs predictive modeling using Random Forest ensemble classification. This is a necessary step because these predictive counts will be matched with the unknown test labels to perform the validations that the predicted output is a truly positive and true negative or not.

4.1 Performance evaluation using PCA in the combination of optimization and classification

The below discussed results are evaluated using extraction done with PCA with the hybrid optimization and classifications. The results are evaluated using Decision Tree, SVM, Ensemble Learning, and Neural Network. It can be seen that the neural network is achieving high performance because it is capable of reducing the training and validation losses by updating the weights which will reduce the biasing error in the information transfer between the layers.

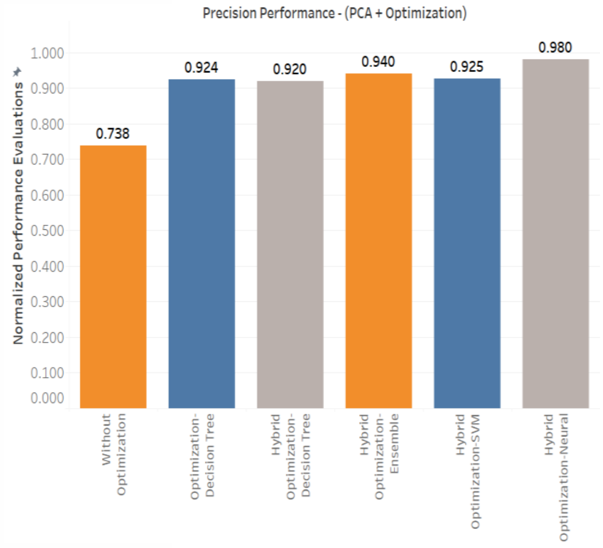


Figure 6: Precision comparison

Fig 6 shows the precision performance in which it can be seen clearly that the ANN using hybrid optimization is achieving high precision in the classification of the true predicted instances for the CAD than ensemble learning, SVM, and decision tree which are closely related to the precise performance. It shows that how many true relevant instances are predicted efficiently as a model performance. If the precision is high the true positive rates concerning the false rejection and false acceptance increases which increases the accuracy of the model. The precision is evalu-ated using the given expression below in equation 1.

$$P = X(p)/(X(p) + Y(p)) \quad (1)$$

Where P is the precision of the model and X (p) is the true positive rate and Y (p) is the false positive rate.

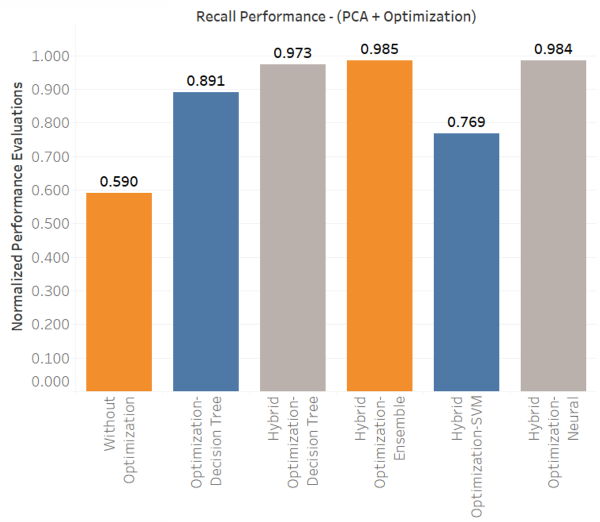


Figure 7: Recall comparison

Fig 7: Recall Comparison shows the recall performance in which it can be seen clearly that the ANN and en-semble learning is achieving nearly the same and high recalling of the relevant instance selections using hybrid optimization in the classification of the true predicted instances for the CAD. Also, it can be seen the SVM is not achieving a high recall rate because of high non-linearity but the decision tree is matching with the performance of the ANN recall rate. Recall shows the relevancy of the prediction is performance based on the training data which should be high. If the relevancy of the prediction is high then there will be high information retrieval and it will increase the high sensitivity of the model. The recall is evaluated using the given expression below in equation 2.

$$R = X(p)/(X(p) + Y(n)) \quad (2)$$

Where R is the recall of the model and X (p) is the true positive rate and Y (n) is the false-negative rate.

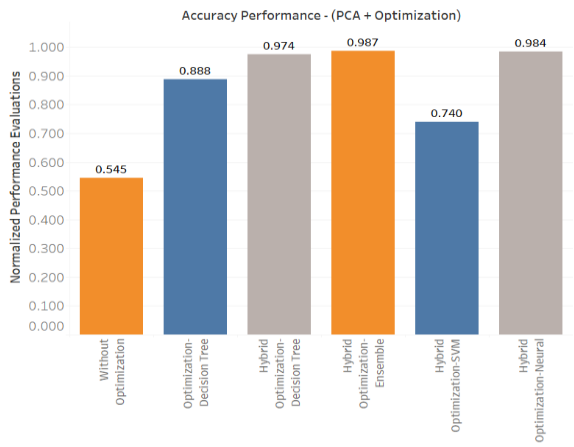


Figure 8: Accuracy comparison

Figure 8: Accuracy ComparisonFig. 8 shows the accuracy performance in which it can be seen clearly that the ANN and ensemble learning using hybrid optimization is achieving high accuracy in classification of the true pre-dicted instances for the CAD and having a very minute difference in the precision value. On the other hand it SVM is achieving low accuracy due to high non-linearity as a result of which the weights become variable and is achieving high variances in the classification rates whereas the decision tree is also achieving good accuracy in the prediction as it reduces the entropy of the data and improves the decision making for the classifications. Accuracy shows the prediction is achieved closely to true values presented in the dataset which should be high for true posi-tive and

true negative rates. If the accuracy is high then classification error rates will

be low for true prediction. The accuracy is evaluated using the given expression in equation 3.

$$A = \frac{X(p)}{(X(p) + X(n) + Y(p) + Y(n))(1 + x)^n} \quad (3)$$

Where A is the accuracy of the model and X (p) is the true positive rate and Y (n) is the false-negative rate, X (n) are the true negative rate and Y (n) false-negative rate.

Table 1: Confusion matrix (Decision tree)

Classes	Actual(CAD =Yes)	Actual (CAD= No)
Predicted (CAD= Yes)	TP (202)	FP (15)
Predicted (CAD= No)	FN (11)	TN (75)

Table 2: Confusion matrix (Ensemble learning)

Classes	Actual (CAD =Yes)	Actual (CAD= No)
Predicted (CAD= Yes)	TP (204)	FP (12)
Predicted (CAD = No)	FN (8)	TN (79)

Table 3: Confusion matrix (SVM)

Classes	Actual (CAD=Yes)	Actual (CAD = No)
Predicted (CAD = Yes)	TP (150)	FP (48)
Predicted (CAD = No)	FN (49)	TN (56)

Table 4: Confusion matrix (ANN)

Classes	Actual (CAD =Yes)	Actual (CAD = No)
Predicted (CAD = Yes)	TP (206)	FP (9)
Predicted (CAD = No)	FN (7)	TN (81)

Table 5: Recall performance

Test No.	Decision tree	Ensemble Learning	SVM	ANN
1	0.973	0.984	0.783	0.983
2	0.952	0.984	0.763	0.981
3	0.954	0.982	0.736	0.977
4	0.973	0.976	0.763	0.983
5	0.967	0.977	0.757	0.985
6	0.963	0.985	0.738	0.972
7	0.954	0.972	0.778	0.987
8	0.957	0.987	0.772	0.983
9	0.968	0.978	0.764	0.982
10	0.962	0.962	0.746	0.975

Table 6: Precision performance

Test No.	Decision tree	Ensemble Learning	SVM	ANN
1	0.926	0.940	0.925	0.970
2	0.921	0.945	0.933	0.969
3	0.930	0.944	0.926	0.961
4	0.925	0.932	0.913	0.967
5	0.922	0.936	0.921	0.976
6	0.935	0.943	0.913	0.971
7	0.928	0.948	0.929	0.957
8	0.936	0.934	0.914	0.961
9	0.924	0.936	0.932	0.956
10	0.937	0.933	0.911	0.973

Table 7: Accuracy performance

Test No.	Decision Tree	Ensemble Learning	SVM	ANN
1	0.971	0.986	0.739	0.983
2	0.966	0.973	0.756	0.981
3	0.973	0.983	0.769	0.986
4	0.977	0.981	0.775	0.973
5	0.979	0.977	0.747	0.988
6	0.965	0.984	0.749	0.981
7	0.966	0.986	0.743	0.983
8	0.972	0.983	0.769	0.985
9	0.969	0.985	0.776	0.978
10	0.975	0.979	0.725	0.983

Table 1, 2, 3, 4 shows confusion matrix using Decision Tree, Random Forest, SVM, ANN. Table 5, 6, 7 shows the comparison of the different test sets run on the CAD classification. The above evaluation shows that the proposed approach achieved high-performance analysis and attained low false acceptance and false rejection rates. It can also be seen that the specificity and sensitivity of the model are also increased and as a result of which the accuracy also increases. Eventually, the proposed ensemble learning using boosting evaluation and ANN is achieving high accuracy rates with low classification error rates.

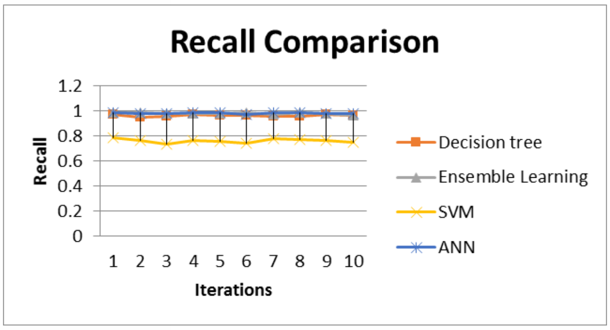
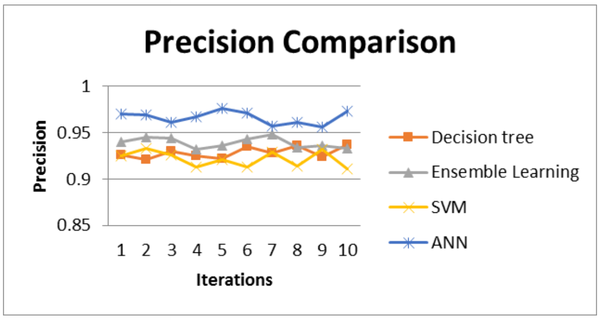
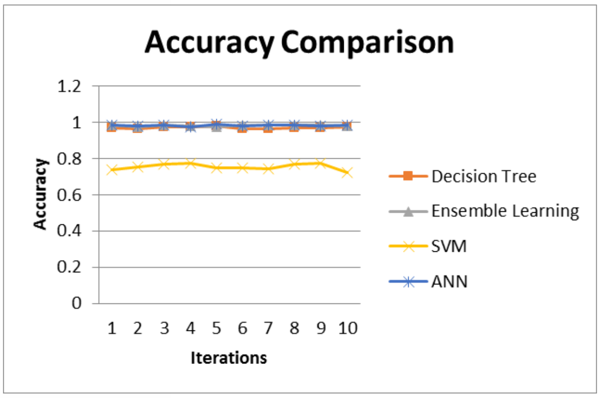


Figure 9(a) Recall performance analysis



9(b) Precision Performance Analysis



9(c) Accuracy Performance Analysis

Figure 9: (a) Recall, (b) Precision (c) Accuracy test evaluations

Fig. 9 shows the performance evaluations of various test cases run on different test samples and performance is evaluated in the same. It can be seen that the performance is achieving high accuracy, precision, and recall for the various test samples and the proposed supervised learning machine learning comparison is achieved. It can be seen that the ANN and ensemble learning is almost similar in performance which shows that the modelling of the data in such a way that the proposed models can achieve high true positive and negative rates.

4.2 Performance evaluation using ICA in a combination of optimization and classification

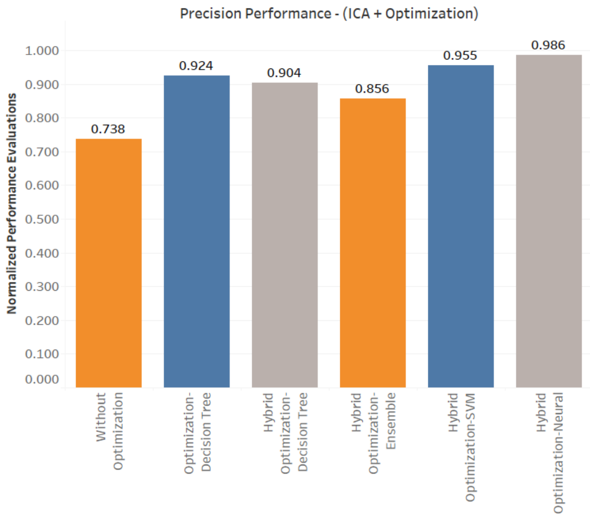


Figure 10: Precision comparison

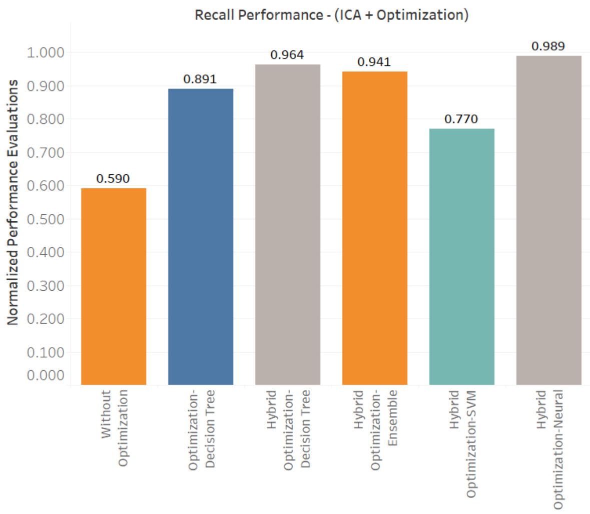


Figure 11: Recall comparison

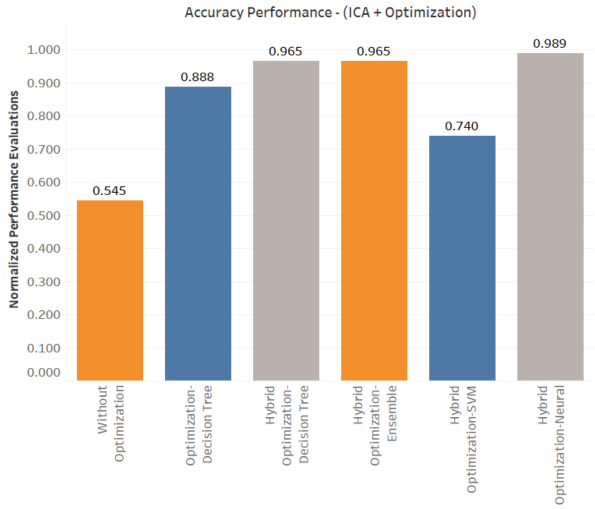


Figure 12: Accuracy comparison

Table 8: Confusion Matrix (Decision Tree)

Classes	Actual(CAD =Yes)	Actual(CAD= No)
Predicted(CAD = Yes)	**TP (204)**	**FP (13)**
Predicted(CAD = No)	**FN (9)**	**TN (77)**

Table 9: Confusion matrix (Ensemble learning)

Classes	Actual (CAD=Yes)	Actual(CAD= No)
Predicted(CAD = Yes)	**TP (206)**	**FP (9)**
Predicted(CAD = No)	**FN (7)**	**TN (81)**

Table 10: Confusion matrix (SVM)

Classes	Actual (CAD =Yes)	Ac-tual(CAD=No)
Predicted (CAD= Yes)	**TP (152)**	**FP (45)**
Predicted (CAD = No)	**FN (51)**	**TN (55)**

Table 11: Confusion matrix (ANN)

Classes	Actual (CAD=Yes)	Actual (CAD = No)
Predicted(CAD= Yes)	**TP (209)**	**FP (6)**
Predicted(CAD= No)	**FN (3)**	**TN (85)**

Table 12: Recall performance

Test No.	Decision tree	Ensemble Learning	SVM	ANN
1	0.964	0.944	0.770	0.988
2	0.954	0.956	0.775	0.989
3	0.966	0.956	0.757	0.988
4	0.967	0.968	0.755	0.986
5	0.968	0.968	0.768	0.978
6	0.955	0.957	0.774	0.976
7	0.969	0.954	0.769	0.989
8	0.958	0.949	0.759	0.986
9	0.969	0.945	0.743	0.989
10	0.954	0.964	0.769	0.987

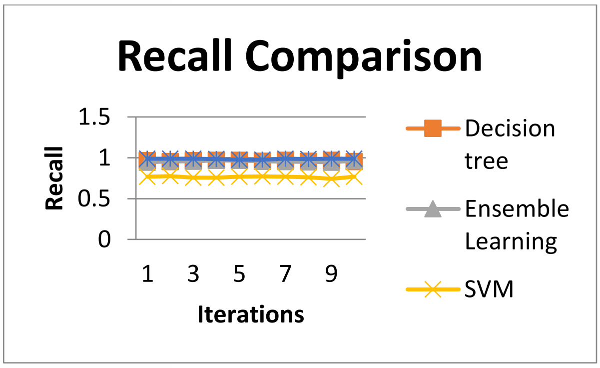
Table 13: Precision performance

Test No.	Decision tree	Ensemble Learning	SVM	ANN
1	0.926	0.940	0.925	0.970
2	0.921	0.945	0.933	0.969
3	0.930	0.944	0.926	0.961
4	0.925	0.932	0.913	0.967
5	0.922	0.936	0.921	0.976
6	0.935	0.943	0.913	0.971
7	0.928	0.948	0.929	0.957
8	0.936	0.934	0.914	0.961
9	0.924	0.936	0.932	0.956
10	0.937	0.933	0.911	0.973

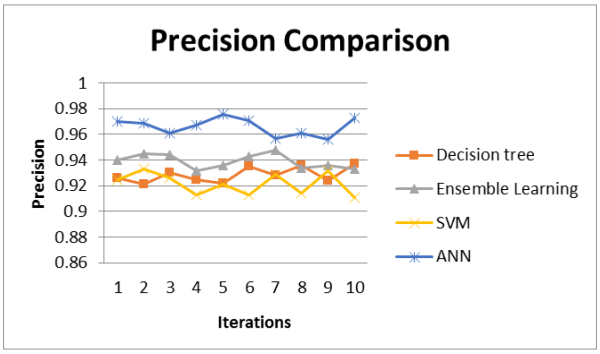
Table 14: Accuracy performance

Test No.	Decision Tree	Ensemble Learning	SVM	ANN
1	0.964	0.963	0.736	0.988
2	0.963	0.971	0.748	0.985
3	0.965	0.975	0.765	0.987
4	0.978	0.974	0.753	0.984
5	0.966	0.969	0.756	0.989
6	0.977	0.971	0.735	0.986
7	0.965	0.973	0.766	0.978
8	0.966	0.989	0.757	0.989
9	0.978	0.961	0.763	0.988
10	0.961	0.973	0.754	0.986

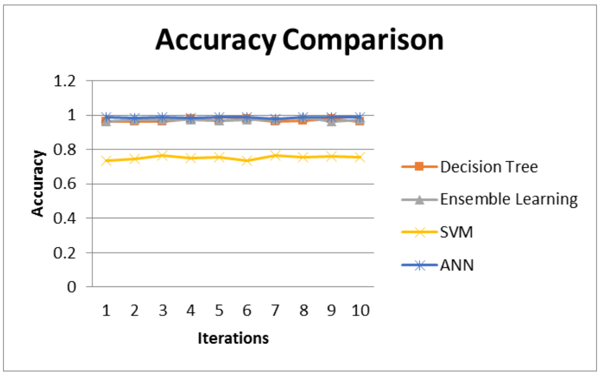
Figure 10, 11, 12 shows precision, recall and accuracy comparison using ICA with optimization and classification techniques. Table 8, 9, 10, 11 shows confusion matrix using Decision tree, Ensemble Learning, SVM and ANN. Table 12, 13, 14 shows the comparison of machine learning approaches after various iterations run on the data and simulated the results. The criteria of overfitting and under fitting are taken care also in the implementation covering all the test cases by using the hyper parameter tuning process. It can be seen that the decision tree, ensemble learning, and ANN is performing well in the detection but SVM is somewhat outfitted the classification because of the non-separable of support vectors on the hyperplane. Also, it can be noticed that the ANN is performing well in terms of the high accuracy, precision, and sensitivity of the model.



13(a) Recall performance



13(b) Precision comparison



13(c) Accuracy comparison

Fig 13: (a) Recall, (b) Precision (c) Accuracy test evaluations

Fig. 13 shows the performance evaluations of various test cases run on different test samples and performance is evaluated in the same. It can be seen that the performance is achieving high accuracy, precision, and recall for the various test samples and the proposed ensemble learning is performing well which is the desired output. The proposed model is tested on various classifiers such as decision tree and ensemble random forest learning process which is achieving high performance in the classification of true positive and true negative rates.

Table 15: Performance comparison

Author's Names	Accuracy
X. Liu, X. Wang et al. (X. Liu et al. 2017)	**92.59%**
J. N. Khiarak, M.F.Derakhshi (J. N. Khiarak et al, 2019)	**94.43%**
N. Pereira (N. Pereira, 2019)	**82.46%**
Devansh Shah (Devansh Shah et al, 2021)	**90.78%**
S.H. Wijaya, G.T. Pamungkas (S. H. Wijaya et al, 2018)	**86.67%**
Proposed Model	**98.88%**

Eventually, the classification is performed with the combination of feature extraction and optimization as instance selections. The test cases implemented using PCA and ICA are achieving efficient and nearer performance and ICA is achieving minute high performance than PCA due to its Gaussian independent nature and a high degree of freedom which will reduce the variance and standard deviation among the data points and also reduces the non-linearity's which will increase the model performances. Performance comparison with different authors is shown in table 15.

5. Conclusions

The proposed work does the comparison of CAD with the help of machine learning algorithms without optimization, single optimization, and a combination of optimization techniques with decision tree, random forest, SVM and ANN classification techniques. Pycharm tool is used with the Z-Alizadeh Sani dataset to analyse the developed model. After pre-processing, the PCA algorithm is applied to a dataset to extract the features. After extracting the features, hybridization of optimization techniques is done by using techniques PSO and FA to improve the accuracy of the developed model. Experiments demonstrate the efficiency of the proposed model. In this paper, the performance is evaluated on different machine learning algorithms because the dynamicity of the data changes the working of the model. So it is necessary to evaluate the performance with at least four machine learning processes. In the proposed model accuracy score is 98.4%. Also, the proposed solution can help clinical experts on our solution because in the dataset almost all realistic features are considered from which any patient suffered for the disease. Also based on the feature engineering process, it can help to find the patterns of the diseases which can help doctors to diagnose the diseases. Based on the precision and recall which is the combinations of true and false measures to achieve the relevance of the data and prediction, the clinical experts can make best use of the proposed solution. From the result and discussion, it can be seen that ANN is giving satisfactory results in comparison to the other algorithms and then Ensemble learning i.e bagging-based random forest is achieving good accuracy nearer to the ANN. The implementation of the Deep learning models with transfer learning will be the future scope of the current approach because as the data grows the complexity of the model will also increase which is the drawback of the current machine learning algorithms.

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Apeksha Mittal received her doctorate in Computer Science Engineering from University School of Information, Communication & Technology, Guru Gobind Singh Indraprastha University, Delhi, in 2021 in the area of Artificial Neural Networks and received a B.Tech. in Computer Science Engineering from Guru Gobind Singh Indraprastha University, Delhi in 2013 and M.Tech in Computer Science from Banasthali University, Rajasthan in 2015. Cur-rently she is working as an Assistant Professor at GD Goenka University, Gurugram. Her key research areas are Artificial Neural Networks, Deep Learning, Machine Learning and Artificial Intelligence.

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The up-scaling organization structure - an integrative approach

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Abstract

The rapid digital change & development in various industry in the 21st century, are the main reasons underlying the importance of developing a breakthrough organization structure design. The consideration is based on balancing the technological capacity (industrial infrastructure up-scaling) and change management capability (organization up-scaling).
The research focuses on creating a design prototype for developing a new conceptual, organizational model, especially for the manufacturing industry sector based on Industry 4.0 technology integrated with a community platform based on digital connectivity, called Society 5.0. This up-scaling model, simulates plug-ins methodology that directly puts on the Techno-structure and Socio-structure aspects on an organizational platform based on the Henry Mintzberg's configuration.
The design of the next generation of organizational structure as conceptual model has been formulated by applying the adaptive platform and up-scaling configuration based on manufacturing industry process base with digital integration and adaptation.

Keywords: Industry 4.0, Society 5.0, Up-scaling, Organization, Mintzber

1. Introduction

Alfred Chandler's (1962) famous idioms "Structure follows strategy" implies that every modern organizational structure shall be developed based on the latest strategy of the organization and therefore successful implementation of an organization's strategy will depend on its primary organizational structure. This is a crucial issue considering that the firms key activities to achieve the firm's strategic purpose mainly depends on the structure of the organization.

In the 21st century, organization's structure will depend on three pillars: leadership, processes, and organization (Chowdhury, 2005). While considering a constantly changing and uncertain business environment, every businessperson must adapt to these changing patterns to remain competitive constantly. Organizations also face and undergo various changes in line with changes in the business environment. Changes can occur in an organizational structure model that becomes more efficient, effective, and conceptual. The emergence of various management and organizational changes is a challenge for every individual responsible for leading and developing the organization—considering that the concept, model, and organizational structure, in general, have not experienced much significant development during the last few decades. The management of social and business organizations also the government are required to participate in continuous transformation, as the impact of uncertain changes that are so radical and disruptive. The challenge is how the organization is managed using the 21st-century paradigm according to the latest uncertain situation and challenges by balancing the infrastructure of Industry 4.0 technology and human aspects (organizations, communities) in Society 5.0.

Organizational structures and management processes can no longer survive inheriting design and management concepts from the past, affecting long-term aspects of productivity and competition. To provide a perspective that Industry 4.0 and Society 5.0 supports organizational transformation processes both at the operational and the scope of the related industry value chains, organizations should have a solid need to experience change and transform. An organizational structure that cannot adopt the concepts of Industry 4.0 and Society 5.0 will cause the inability of every internal element to respond to market needs with an adequate supply speed. As the result of Industry 4.0 and Society 5.0, many industries are under intense competitive pressure. Therefore, the industry must design its organizational structure to encourage continuous and progressive innovation. Centralization in organizations as an organizational structure does not reflect current needs (Çakırel, 2016). It is made possible due to the urge to use more initiative, the courage to take risks, make innovations, and individual freedom within the organization (Mintzberg et al., 2010).

The complexity of competition challenges in an industry can occur from within the organization and environmental dynamics; this means both internal and external contexts are complex. Assuming a two-way complexity effect between these two factors, the dynamic condition will always urge the organization to adapt. The level of complexity adopted by a company is an adaptation formulation that carefully considers the internal and external complexity. The ingredients of this formulation are management decision problems (Moldoveanu & Bauer, 2004).

The level of diversity and complexity of the organizational structure becomes a challenge in this study to obtain an overview of the basic organizational structure of an industry (manufacturing based). The context of up-scaling in the proposed Organizational Structure design model for companies based on the manufacturing industry measures the level of adaptation and new complexity that the industry need. The new level of complexity internally is in responding to the development of the implementation of Industry 4.0 technology in aspects of the production process and services. Meanwhile, the new competition complexity externally is the demands of B2B, supply chain, distribution line, B2C, the world of education, society, and the government as communities that must be involved and collaborated on a platform according to the demands of Society 5.0.

2. Literature review

Any today's organization is constantly faced with change (Hugentobler, 2017). Organizational transformation is an increasingly important concept and is a continuous process. The impact of a transformation process on an organization will allow it to continue developing sustainably. This transformation process is carried out to obtain a level of effectiveness and efficiency through adapting to changing opportunities and challenges (Schalock et al., 2018). The digital process, especially with the advent of Industry 4.0, has changed the format of the organization, and this change has led to several circumstances where the organization can barely cope. Organizational change or transformation challenges requires continuous organizational development (Sousa & Rocha, 2019). Therefore, continuous efforts are needed for organizations to transform from an actual physical environment and infrastructure into a virtual platform with the support of information and communication technology that continues to grow. The information and communication technology will be the primary basis of all elements of future organizational functions. The perspective of Industry 4.0 will always involve a comprehensive digitalization process with the consumer handling process to the production and service processes (Wilkesmann & Wilkesmann, 2018)

Based on the base reference above, organizational transformation is needed as the best solution in answering various challenges within the organization to adapt and optimize the added value of Industry 4.0 and Society 5.0. Thus, along with the success of the organizational transformation process challenges, the expected positive impact is the potential for improving business and service performance which can positively affect economic growth and development (Esmer & Şaylan, 2019). So, this research is basically following principal and important three questions that must be considered to avoid possible mistakes in initiating and designing/redesigning organizational structure changes (Peter et al., 2019), which are:

- How to choose the right organizational development and competition strategy?
- How to select and determine organizational performance measures in the event of a change?
- How to select adequate organizational design/redesign methodologies?

2.1 Organization structure & design

The early research on organizational design conducted by Pitts & Clawson (2008) put forward how organizational structures should be adapted and developed. Their research confirms that organizational structures can develop optimally through the capability and culture of creativity. The research also concludes that the form of design and organizational structure will continue to evolve according to the developments and needs of the times and believes that new principles will be discovered and used. Continued by Krebs (2007), wherein in a knowledge-based economy, the impact on the industry is the emergence of dynamic needs for organizational structure transformation. The dynamic occurs across industries and has resulted in recommendations to formulate a new structural approach, which can adapt to information flow and knowledge sharing in the information age. Meško (2016) investigates the impact of Industry 4.0 complexity on the operational activities of organizations seeking to transform. The research has found that Industry 4.0 leads to an unprecedented "Cross Complexity." The term defines the existence of a new level of connectivity called IoT (Internet of Things).

IoT connects all operational networks that have extreme relevance in an industry or business and become the basis of prerequisites or standards for all operational aspects of the organization to enter the Industry 4.0 level. At the end of 2020, Aquilani & Michela's (2020) research found that the company or industry in the era of integration of Industry 4.0 and Society 5.0 is the best place for innovation processes that directly impact the community and related communities. The organization must continue with its unique structural design to be the best platform for parties' industry and community involvement. The previous related research conducted by Esmer & Şaylan (2019); recommends three main elements in the business world to collaborate and integrate. These three elements are industry, government, and community organizations. Based on those elements, changes can occur in an organizational structure model that becomes more efficient, effective, and conceptual. The emergence of various management and organizational changes is a challenge for every individual responsible for leading and developing the organization—considering the concept, model, and organizational structure, to adapt the growing innovation and significant digital integration in the last decade.

2.2 Digital organization

The term 'digital organization' is a new form of network organization format. Digital organization is a complex phenomenon that focuses on coordinating non-hierarchical structures, products and services that are detailed and rich in information and correlated with aspects of human insight and knowledge (Drucker, 2020). All of these elements are supported by information and communication systems which are important aspects of digital organizations.

Digital organization is applied when the boundaries of time, geographical space, organizational form, and access to information are completely replaced by the use of Information and Communication Technology. A digital organization can also be defined as a temporary network of independent companies - suppliers, customers - linked by information technology to share skills, costs and core competencies (Sousa et al., 2019). The introduction of digital products, services, channels and interfaces has become a challenge for leaders of non-digital companies to redesign their organizations according to digital formats and platforms. Because digital organizations must be linked and integrated into other parts of the company and their respective social environments, digital technology introduces a new dimension of organization that was previously independent. (Sousa et al., 2019). This major change shows that digital technology has transformed all types of industries today.

The Industry 4.0 and Society 5.0 will make organizations digitally transform and integrate the internet, machines, people, and things in the simplest definition. Industry 4.0, when fully adopted, will indeed change the whole concept and activity of the organization (Özsoylu, 2017). As for the hypothetical formulation, the up-scaling approach was designed to find breakthrough strategic organization competitive advancement scientifically and implementable in the industrial sector directly affected, especially manufacturing with the Industrial revolution 4.0 and The of Society 5.0. Thus, it can provide a new perspective on adaptive steps in the manufacturing industry, mainly to balance the competitive capacity development process in technological aspects related to industrial technology 4.0 improving organizational management. On the other hand, with Society 5.0, inevitably, this swift current of change will also affect organizational life and interactions. In this context, organizations need to adapt to Industry 4.0 and Society 5.0. The results obtained in the research takes a position in updating the shifting of the latest organizational structure models and concepts due to current digital industry era.

2.3 The mintzberg theory

Mintzberg (2009) describes the organizational structure as "coordination in which HR is divided into different tasks, and these tasks are reassembled for a common goal." The structure is formed with five coordination mechanisms, five organizational structural components, and nine design parameters. In addition, the primary coordination mechanism is based on mutual trust between individuals in an adhocracy organizational structure (Sunje et al., 2010). The five structural components of the organization that are the model of Mintzberg are as follows in the Figure 1:

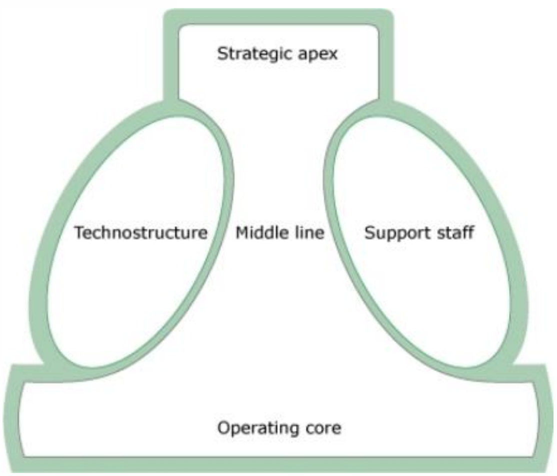

Figure 1. The mintzberg's platform

As described in the above figure 1, the five elements of the Mintzberg platform are:

- "Strategic Apex" is a collection of functions that provide organizational strategic direction and decisions
- "Middle Line" is a collection of managerial functions from the primary operations of the organization
- "Operating Core" is an organizational front-liner who is directly involved in the implementation of all operational aspects of the organization
- "Techno Structure" is a function that carries out the operational analysis process and the aspects needed for capacity building and organizational performance
- "Support Staff" are support functions within the organization that help the needs and smoothness of the organization's core operational and managerial aspects.

2.4 The industry 4.0 and society 5.0

The Industry 4.0 was first introduced in 2011 in Hannover, Germany, as a proposal for the development of a new concept of German economic policy based on a high-tech strategy (Mosconi, 2015). The concept, which was launched as the fourth technological revolution, is based on concepts and technologies that include Cyber, Internet of Things (IoT), and Internet of Services (IoS) (Hoffmann et al., 2014), based on real-time communication via the internet that enables continuous interaction and exchange of information not only between humans (C2C) and human and machines (C2M) but also between machines (M2M) themselves (Cooper & James, 2009).

As a consequence of Industry 4.0, Society 5.0 emerged, whose initiative was initiated in Japan. This new revolution initially emerged due to concerns of an aging population (Pereira et al., 2020). Society 5.0 focuses on using the tools and technologies developed by Industry 4.0 to benefit humanity. Society 5.0 focuses on positioning humans at the center of technological modification and innovation for the benefit of mankind and is considered a silent revolution that started in Japan that promises to revolutionize society (Costa, 2018). The main goal of Society 5.0 is to improve the quality of life of the community by using the potential obtained by Industry 4.0 (Ferreira, 2018).

One of the positive aspects of Industry 4.0 is creating added value effects, especially in the efficiency of operational and SCM processes with new disruptive competitive business models. However, technological changes may have positive and negative impacts on the organization format. The challenge is how to carry out the organizational restructuring process properly because some elements and functions within the organization will soon disappear (Kane et al., 2015). Thus, concerning Industry 4.0, organizational and industrial management cannot limit adjustments and adaptations only to the automation aspects of the production process. The Industry 4.0 platform is the digitalization of business processes as a whole (Meško, 2016). In addition, the added value of organizations in the Industry 4.0 era is finding creative and alternative solutions to produce new products and new competition solutions (Kane et al., 2015). In previous global-level studies, it can be seen that there is a need to explain and further examine the linkages between Industry 4.0, Society 5.0, and organizational transformation. Research shows a very close relationship between Industry 4.0 and the process of organizational transformation (Esmer & Şaylan, 2019). Thus, organizations that apply the latest principles in Industry 4.0 and Society 5.0 should carry out the transformation process to address challenges and problems in business, economic, social, technological, political, and legal aspects. In addition, especially with Industry 4.0 encourages organizational formats to be digitized on every aspect of its business activities (digital organization). Without carrying out adaptation and transformation, an organization may not successfully implement the Industry 4.0 models and concepts in their entirety in their operational activities (Hugentobler, 2017).

3. Methodology

Based on the five elements in Mintzberg platform theory, it is necessary to establish a scientific platform of the proposed conceptual organizational structure, which will become the theoretical reference for the research. Based on this need, the organizational structure design developed in the modelling uses concepts based on the configuration and components of Mintzberg's organizational model. The underlying aspect is that Mintzberg's configuration has a representative platform because it has a concept with an inward-looking capacity that is integrated and adaptable to the business processes of any manufacturing industry. Despite its apparent flexibility, Mintzberg's configuration can accommodate any organizational structure model used by most of manufacturing industry. The most important aspect is the ease of customization and is scalable with the development of the industry. Another aspect of excellence is that Mintzberg's configuration was initially designed to be adaptable and flexible to the organization's external environment dynamics. This is under the research focus, which develops an outward-looking organizational structure design with the developments and dynamics of Industry 4.0 and Society 5.0. Mintzberg (2009) stated that the organizational structure must be flexible because it operates in a competitive and dynamic environment.

Mintzberg's platform will then integrate into an upscaling organizational structure design concept based on the adoption of Industry 4.0 and Society 5.0, and the distinctive contours of manufacturing-based industries. The integration approach with an outward-looking organizational structure design perspective due to dynamic competition and challenges in today's digital economy, technological advances, new digital trends, globalization, organizational strategic issues and the growth of customer expectations (criticism) through social media. The situation triggered a model change or a paradigm shift in the function of the industry's organizational structure and management approach. These show that Industry 4.0 and Society 5.0 answered the challenges of the global industrial world, with fast processes and disruptive changes involving various other industrial sectors to improve the total efficiency of productivity and supply capability of the organization. In addition to its advantages, Industry 4.0 has become a new business model (Ibarra et al., 2018) that requires changes in the logic or operating philosophy of the organization and how the strategic issues are managed. These changes will bring impact to a need to break away from the traditional organizational structure style. These finding challenges conducting a more in-depth study of the Organizational Structure design, which is characterized by adaptive, integrated, and scalable.

It is crucial to consider the following steps before applying the organizational modelling and simulation methodology. The crucial step is modelling and simulation, where experiments have to be carried out. The results will then be analyzed within the scope of the organizational benchmarking model from the previous structure format, and the reference organization (Peter et al., 2019). The basic assumption is that if it can describe the inputs, outputs, structures, processes, and the linkages in an organization in detail, then the research model can simulate them appropriately. The better the understanding of organizational reality, the better the model can be. The organizational structure transformation methodology provides an opportunity to develop a model by supporting facts, changes, or new needs through simulation techniques. Another consideration is that all flows (processes) within the organizational structure trigger customer demand (information) or market needs. Customers can be outside and inside the organization.

3.1 The integration method

The relevant literature review is undertaken to create visual aspects in the format and contours of the proposed conceptual Organizational Structure (Up-scaling). Also, additional methods are needed to translate and articulate all the data and qualitative analysis obtained from the literature review to obtain a new meaning in the form of rational arguments that can be compared according to the research context. The steps and analysis model are described in the

Figure 2:

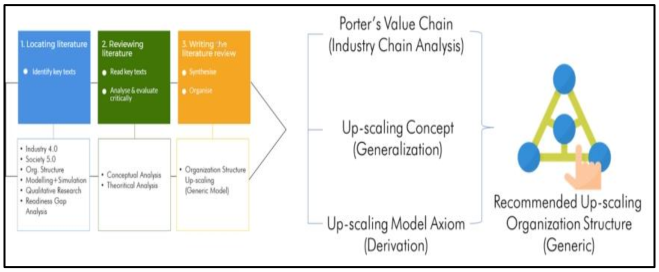

Figure 2. Integration of literature review and visualization of proposed model

In the Figure 2. Above. there are three analytical approaches to be able to articulate all qualitative data as a result of the literature review, namely:

- Porter's Value Chain, which is used as a generic competitive advancement reference for mapping an organization's internal (value) systems and analyzing supporting industry chain capacity based on the contours of the related industrial sector. With this Value Chain approach, a complete description (profile) of organizational elements will be obtained from each organization representing the related industrial sector, including industrial and social supporting communities according to the theme of Society 5.0
- Up-scaling Concept. Whereas all the literature review results on the concepts from Industry 4.0 and Society 5.0 are generalized to become the basis for the modification (Up-scaling) of Mintzberg's configuration. This concept is the primary reference for the multi-tier organizational structure development model for designing the proposed research organizational structure model.
- Up-scaling Model Axiom. At this stage, a statement or central axiom is formulated and established, as the basis for developing the up-scaling organizational structure model. This axiom is a statement put forward due to the analysis accumulated and actualized in the synthesis of design elements of the conceptual up-scaling Organizational Structure model of the research proposal.

3.2 The upscaling plug-in method

The proposed model and design of the next-generation organization structure model should meet all the required elements. To make it possible, a "plug-in" simulation process is carried out on the generic organizational design aspects and elements from Industry 4.0 and Society 5.0 in a new organizational form according to the field. This "plug-in" simulation process is carried out with Industry 4.0 in the Techno-structure aspect and Society 5.0 elements in the Socio-structure aspect as a form of modification and up-scaling of the traditional Mintzberg's platform. The simulation process of this "plug-in" can be seen in the Figure 3.

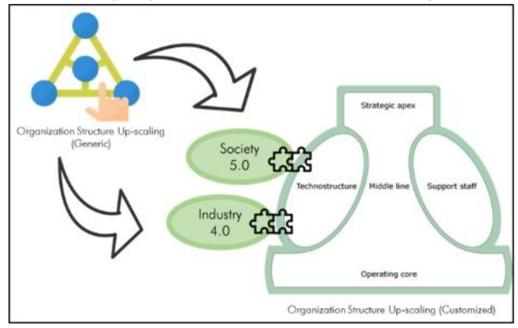

Figure 3. The plug-in simulation method

Before the plug-in process is carried out, it is necessary to reformat the organizational structure that will be up-scaled by transferring it to Mintzberg's configuration platform format by going through several stages, namely:

- Identify the main activities (core activities) of the representative Company's business processes described in the connectivity of the leading and supporting functions in the Organizational Structure.
- Identify all organic functions that exist within the organizational structure of a representative company to be aligned with the contours of the five main elements of the Mintzberg's configuration platform, namely Strategic Apex, Middle Line, Operating Core, Supporting, and Techno Structure
- Move all organic functions within the organizational structure of a representative company according to each function or element of Mintzberg's configuration.
- Ensure that all organic functions are aligned between the standard organizational model in each representative Company and the organizational model that uses Mintzberg's configuration platform.

4. Result & discussion

The diversity of organizational structures within a highly competitive industry shows how the management adapts to the unique contours of the complexity of the supporting industrial pyramid, technology, and production processes, and especially the business development strategies carried out within a company. The basis for adapting the organizational structure design applied in an industry by considering the details and contours of this complexity can be divided into three sub-components: the number of elements in the system, the number of connections between elements, and the type of functional relationship between elements (Milling, 2002).

4.1 The axioms modeling

By considering the dynamics of Industry 4.0 and Society 5.0 as well as the results of the previous literature analysis, becomes the basis for formulating the following modelling axioms formulation:

A1: Axiom 1. (grand theory: alfred chandler)
"Organizational structure is designed to follow the development of business strategy."

A2: Axiom 2. (basic: up-scaling)
"The new organizational form is an enhancement to the contemporary application of pre-existing organizational solutions."

A3: Axiom 3. (main reference: mintzberg theory)
"The platform of the organizational structure must be flexible because it operates in a dynamic environment."

A4: Axiom 4. (basic: modeling)
"The organizational structure with the new model represents the development of the information flow management function and the adaptation of the latest operational processes of business and industry."

A5: Axiom 5. (Adaptation: industry 4.0 and society 5.0)
"Digital development focuses on adapting knowledge, business processes, supply connectivity, added value and online collaboration, thus creating opportunities for organizations to develop their forms and designs."

In equation form, the integration of the five axioms above becomes:

$$A1 \overset{\Delta}{\longleftrightarrow} A5 \otimes A4 \rightarrow A3 \oplus A1 \supseteq A2$$

Note:

$\overset{\Delta}{\longleftrightarrow}$ (defined by), $\otimes$ (relation), $\oplus$ (structure), $\rightarrow$ (logical implication), $\supseteq$(inclusion)

Thus, the next step is to integrate the basic design of the conceptual Up-scaling Organizational Structure model design. Based on the above axioms, it can be interpreted that adaptation and integration to new complexities (cross complexity) are needed in the value-added chain of the manufacturing industry. The internal and external challenges appear to the organization during the up-scaling stage of the production process infrastructure and its services towards Industry 4.0 and Society 5.0. Organization and management issues related to this new complexity occurs in changes in work procedures and production stages. It touches all organizational functions in the Strategic Apex, Middle Line, Operating Core, Support, and Techno-structure arrangements. Since it is related to the concept of Society 5.0, it is necessary to add (add-on modification) aspects within the organization with Mintzberg's format, namely Socio-structure. The point is that Industry 4.0 technology directly touches the Techno-structure aspect within the organization. At the same time, Society 5.0 requires adaptation (modification) of new elements in Mintzberg's platform concept to be integrated within the organization, namely Socio-structure.

4.2 The up-scaling structure model

For the based conceptual organization structure, adaptation is made to the organizational configuration platform on a Mintzberg's format to align with the thematic adaptation of Industry 4.0 and Society 5. As for Industry 4.0 terminology used is Digital Connectivity Operation Management (DCOM). As for thematic related to the concepts and contours of Community 5.0, the terminology used is Smart Community Connectivity Management (SCCM). According to Mintzberg's configuration, the thematic used for Strategic Apex on strategic decision-making in the manufacturing industry is “Business Management”, which is applied to the Middle Line aspect. The thematic used for the end-to-end daily operational activities of the manufacturing industry is "Operation Management." While the thematic used for the Operating Core aspect is "Production Management," this is due to the model's base design being rooted in the manufacturing industry. Furthermore, the thematic used for the Supporting aspect is "Operation Support," with the goal that all organic functions in this thematic have service competence and a pro-active attitude in supporting function and performance of all thematic within the organization.

The integration of the Mintzberg's configuration format with Axioms formula adaptation to Industry 4.0 and Society 5.0, makes the propose up-scaling organization structure as seen in the Figure 4:

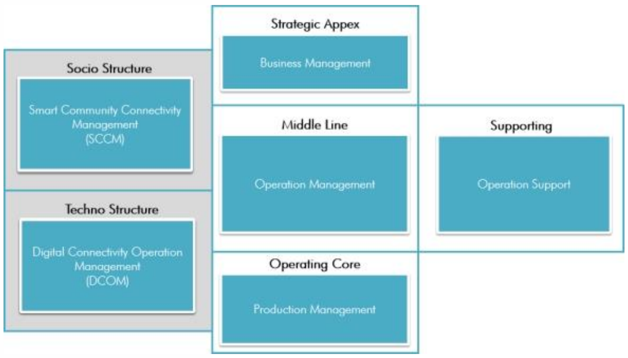

Figure 4. The up-scaling organization structure design

The structure of the up-scaling organization structure design in figure 4 above shows that the proposed platform can be implemented and adapted in the organizational structure base of the manufacturing industry. The platform also covered all business and operational processes as in the central thematic (core processes) called Business Management, Operation Management, Operation Support, and Production Management. Meanwhile, in the Techno-structure aspect, it becomes a competitive advantage option if a manufacturing industry has an organic function within its organization that optimizes technology management related to Industry 4.0 and developments in aspects of products, services, and manufacturing processes through R&D. On the other hand, the application of the Socio-structure aspect in the manufacturing industry organization is an added value and respect for the related community. The ability to have Socio-structure elements adapts to the capacity and role of the organization to its stakeholders and acceleration into the concept of Society 5.0 can only be possible after digital integration of Industry 4.0 technology within the organization.

5. Discussion

The added value of change strategy in the era of Industry 4.0 in global wide and Society 5.0 in global perspectives is a challenge to provide digital integration solutions to organizations. The important role of developing the supporting organization, can no longer be routine and administrative but must be digitally progressive. The implications of these digital strategic role are the basis for determining aspects of achieving the competitive performance targets of an organization. Management must manage the interaction of all elements inside and outside the organization with the latest approach that runs parallel to the development of business and digital technology.

The development of organization structure concept and platform with up-scaling design as conceptualized in this research is a scientific response in answering the integration of improving technology infrastructure and developing integration capacity and competitive advancement within an organization. A new organizational concept with up-scaling platform will undoubtedly have its own impact, especially in the strategic aspect where the classic organizational function, a platform in gathering all exclusive elements, becomes open with communal and inclusive team members.

Significant challenges in discussing the development of adaptation within an organization to its internal dynamics and environment will always be interesting topic to discuss for organization design enthusiast and professionals. So far, there has been a dichotomy in the concept of organizational design, whether to follow business processes that must be adapted thoroughly or to consider the dynamic demands of the related external environment. Choosing one or both will always pose challenges to the strategic aspect, which is the main element in the organization. The dimensions of the up-scaling organizational structure as a result of conceptual design will provide a new nuance in mapping the organization competitive advancement features related to product, technical aspects and behavioral elements also aspects of communication and managing relationships with the industrial community and markets and stakeholders. This competitive challenge makes the role of management and scientific researchers in organization capacity development need to look further concerning the emergence of multi-talented needs based on digital attitudes at various levels of the organizational structure.

The existence of an up-scaling organizational design concept platform has logical consequences in that all related operation functions in a modern organization, particularly one based on digital technology, must rely on internal human resource capacity and open a digital collaboration platform with its stakeholders. The strategic impact on organizational aspects is primarily how to manage and integrate the colors of corporate values and the new organizational culture based on traditional business philosophy, digitalization, and virtualization. This is a new era of strategic organization challenge in Industry 4.0 and Society 5.0, where human management touches on the virtual aspect and its seamless connectivity in the digital world, as well as physical visualization and actualization. Therefore, it is critical to use the most recent organizational platforms.

6. Conclusion

Organizing bring new competitive advancements in management; if it can be appropriately managed, it will contribute to greater operational effectiveness and efficiency in order to achieve the competition goals. In the organization, determining the optimal organizational structure needs to be done appropriately to support the business strategy.

Based on the above-defined axioms and propose conceptual design, it can be interpreted that adaptation and integration to new complexities (cross complexity) are needed in the value-added chain of the manufacturing industry. The internal and external challenges appear to the organization during the up-scaling stage of the production process infrastructure and its services towards Industry 4.0 and Society 5.0. Digital adaptation and operational management issues related to this new complexity occur in changes in work procedures and production stages. It touches all organizational functions in the Strategic Apex, Middle Line, Operating Core, Support, Techno-structure and Socio-structure. The point is that Industry 4.0 technology directly touches the Techno-structure aspect within the organization. At the same time, Society 5.0 requires adaptation (modification) of new social-related elements in Mintzberg's platform concept to be integrated within the organization.

The development of an organizational concept platform with up-scaling design as conceptualized in this study is a scientific response in answering the integration of improving technology infrastructure and developing talent capacity and decision-making competence within an organization. A new organizational concept with an up-scaling platform will undoubtedly have its impact, especially in the SCM aspect where the classic organizational function, a platform in gathering all exclusive elements, becomes open with communal and inclusive.

It is also shown that the design of the up-scaling organizational structure model has become a representative visualization that can be a scientific reference for the development of the latest organizational structure, especially in the manufacturing industry based on Industry 4.0 technology and its development towards the Society 5.0 platform.

There are several limitations to this research, which focuses mainly on developing a concept model of an organization based on Industry 4.0 and Society 5.0. Another limitation is the limited literature on Industry 4.0 and Society 5.0. As a result, future research must carefully observe the dynamics of the industrial world and digitalization in general. This is significant because the implementation aspect of the organizational structure is highly dynamic and adaptive. As for the focus of future research, it will be based on the model design from the results of this study in order to develop aspects of the scope of the Up-scaling organizational structure prototype to the smallest organizational structure level. This is necessary in order to touch the functions and positions within the organization related to operational aspects on the production floor, customer service, administration, and front-liners.

Finally, it is critical to disseminate the research findings, specifically the design of the Up-scaling organizational structure model, to relevant parties in the industrial world, academia, and the general public at both the national and international levels in order to obtain feedback for its application and further development, particularly in the field of organization development theory.

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BIOGRAPHY

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Intelligent ocean wave height prediction system using light GBM model

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Abstract

Forecasting the heights of marine waves is an important tool for offshore and coastal engineering and a huge undertaking in marine detection and warning. However, a precise forecast of the Sea Wave Height (SWH) is challenging and outstanding to waves' volatility and fluctuation characteristics. Therefore, our research proposes an Intelligent Ocean Wave Height Prediction system using a light gradient boosting machine learning. Initially, this research extracts the wave speed, peak wave direction, zero up crossing wave period, wave period, and SWH, among the wave-based properties. Then, the retrieved data are fed into the proposed light GBM, which operates well with the high-dimensional data that makes our proposed approach easy to interpret. The proposed method can also be utilized to estimate wave height because light GBM performs with redundant data in time-window-size data and is noise-insensitive. Experimental results reveal that our light GBM significantly improves the accuracy of numerical predictions of ocean wave height. When compared to the baseline, our proposed approach achieves lower error than the Multilayer Perceptron Neural Network (MPNN), Cascade Correlation Neural Network (CCNN), General Regression Neural Network (GRNN), and Radial Basis Function Neural Network (RBFNN), with error rates of 5.01 %, 44.33 %, 6.22 %, and 2.23 %, respectively. As a result, our proposed technique has a lower MAPE of 2.21 % compared to baseline approaches.

Keywords: Sea wave height, light GBM, Machine learning, Forecasting, Wave variables.

1. Introduction

Marine disasters represent a danger to many countries worldwide, resulting in massive deaths and economic damage. The growing growth of a variety of offshore businesses has piqued attention in the effective wave forecast characteristics [Hashim et al., (2016)] [1998]. High-energy ocean waves Significant Wave Height (SWH) can collapse ships and finish marine or seaside infrastructure. It endangers human lives, agriculture output, and the long-term viability of aquaculture goods. Wave height in sea forecasting is a difficult and significant issue in seaside and marine engineering due to waves' difficult and unpredictable nature [Amin, (2013)]. It is essential to estimate marine wave heights promptly and precisely in disaster warning and emergency prevention, as well as the development and renovation of seashore area construction, marine transportation, and environmental protection [Sabatier, (2007)]. As a result, accurate SWH forecasting is crucial since it can help reduce societal and business losses.

Furthermore, Sea Wave Height forecasting can provide certain advantages. Altunkaynak & Wang, (2012) created a new approach for predicting SWH by combining a genetic algorithm with Kalman filtering. These approaches reduced mean relative and mean square errors over ANN and demonstrated its superiority. Improved ship routes based on Sea Wave Height forecasts, for example, could skip stormy sea regions, reducing sailing time and fuel expenditures. Moreover, forecasting sea wave heights can give valuable information for the army and naval planning activities. Sea wave height forecasting systems have been developed for years due to their relevance and practical uses. Empirical and numeric form Sea Wave Height prediction algorithms had tremendous comprehensibility at the beginning, but low performance and generalization capability. Moreover, the authors [Nitsure et al., (2012)] used genetic programming to forecast wave heights based on wind data. Prediction findings with lead periods of up to 12 and 24 hours were satisfactory, with coefficients of correlation between predicted and measured values greater than 0.87.

When predicting ocean wave heights, a variety of methodologies can be used. For meaningful wave height forecasting, experimental, mathematical, and soft computing methodologies have been described. Tidal variation, wind blowing in different directions, the depth and physical qualities of water are all external elements that affect the wave's speed and height. In a numerical model that incorporates wave propagation, these physical processes and interactions are represented as a different equation. To overcome the challenges in the wave propagation model, a powerful computational infrastructure is usually necessary. Prahlada & Deka, (2015) attempted to create a hybrid wavelet and artificial neural network model for SWH prediction beyond multistep lead time by utilizing the advantageous properties of both. The given strategy has been demonstrated to be both effective and practicable. This method requires creating a physical design of the tallness of a sea wave, which necessitates a thorough understanding of basic physical methods, as well as a significant financial investment and time commitment [Yoon et al., (2011)]. When an emergency scenario occurs in the water, faster and more precise forecasting systems must be developed to estimate wave heights rapidly. For example, in [Deo et al., (2001)] the authors suggested a 3-layer feed-forward network model that forecasts the heights of ocean waves in various seas and examines the characteristics that impact ocean wave height prediction. The authors [Zamani et al., (2008), Malekmohamadi et al., (2011] investigated many data-driven designs based on Artificial neural networks (ANNs) and Instance-based learning in-depth (IBL). Experiments revealed that ANNs had a modest edge over the IBL in forecasting severe wave conditions, and ANNs also have a competitive advantage in predicting extreme wave conditions. Mahjoobi & Etemad-Shahidi, (2008) using Support Vector Machines, developed a model for estimating the heights of ocean waves and, discovered that the Support Vector Machine validation loss is lower than the traditional neural network [Mahjoobi & Mosabbeb, (2009)], the effectiveness of arrangement and regression trees in predicting the heights of marine waves was explored. The forecast findings suggest that the decision tree can be utilized as an effective method with a reasonable error range. However, predicting wave heights based on information about storm generation is essentially an indefinite and unpredictable method that is hard to represent using deterministic equations. Machine learning approaches employ statistics to understand better the spatial and temporal relationships buried in historical time series. It makes it a perfect option for a machine learning model. It focuses on detecting a probability plot in a set of input data and then applying the same strategy to forecast the desired attribute. This research paper's primary feature is as follows:

Traditional empirical or numerical-based forecasting models are used in existing research, but they have speed and accuracy constraints. Our research introduces light Gradient Boosting Machine (light GBM), which accurately predicts wave height by overcoming the problems in existing research, and we remove the wave height column from the data frame to avoid loss.

The following is how the rest of the article is put together: Section 2 discusses the associated work. The proposed technique, including its processing phases, is discussed in detail in Section 3. Section 4 explains the outcome of the research. Section 5 concludes with the findings.

2. Related works

Due to the difficulties of data gathering and processing power limits in the previous century, SWH prediction is primarily based on actual or mathematical models. Leading to a shortage of intellectual processes, these strategies have high readability but poor prediction accuracy and poor applicability. Due to the rapid evolution of ML theory, many ML methods, such as Support Vector Regression, Bayesian Network, XG Boost, extreme learning machine, and ANN, have been successfully employed in Sea Wave Height forecasting. In contrast to prior empirically or numerically based "hard computing" methodologies, these approaches were called "soft computing."

Cornejo-Bueno et al. [Cornejo-Bueno et al., (2016)] proposed employing a hybrid clustering evolutionary algorithms, an extreme learning machine technique for marine energy applications in SWH and flow prediction, and received positive results.

Abhigna et al. [Abhigna et al., (2017)] investigated SWH prediction by means of correlation Coefficient (CC) and Mean Square Error (MSE) for Feed Forward and Recurrent Neural Networks trained using Levenberg Marquardt (LM), Conjugate Gradient

(CG), and Bayesian Regularization (BR). A year's worth of data from anchored buoys in the Bay of Bengal was utilized to train the network, and data for the next year was anticipated. Compared to other techniques, the Recurrent Neural Network with Bayesian Regularization fared the best.

Nikoo et al. [Nikoo et al., (2018)] used a fuzzy K-nearest neighbor (FKNN) model to forecast Sea Wave Height, where wind direction changes affect fetch length. FKNN outperformed BN, regression tree induction, and support vector regression in terms of wave height prediction, especially for wave heights greater than 2 m. Wei and Hsieh [Wei & Hsieh, (2018)] used ANN in two settings to examine the feasibility of forecasting waves using data from a neighboring buoy. The study found that the model incorporating information from the neighboring buoy outperformed the existing works. Wang et al. [Wang et al., (2018)] used a Mind Evolutionary Algorithm-Back Propagation neural network hybrid method (MEA-BP). Yang et al. [Yang et al., (2019)] aimed to forecast SWH based on a CS–BP model, taking into account the edges of backpropagation neural networks (BP) and cuckoo search algorithms (CS), and the suggested model has good potential for wave height prediction. In a recent study, Zhang and Dai [Zhang & Dai, (2019)] used the conditional limited Boltzmann machine in the traditional deep belief network to forecast SWH. The measurement criterion demonstrated that the newly suggested technique is quite good at predicting short-term and severe occurrences. Son et al. [Son et al., (2020)] used the bi-directional convolutional Long Short Term Memory technique to estimate real-valued Sea Wave Height from a series of consecutive ocean photos, and they got low error indices.

Fan et al. [Fan et al., (2020)] consumed Long Short Term Memory to predict Sea Wave Height with greater accuracy for various forecasting time horizons and developed a simulating wave's nearshore-LSTM to generate a single-point prediction. A lot of earlier research on SWH prediction has focused on employing superficial machine learning models like BP, SVM, etc. Still, they have failed to leverage the deep correlations between historical data over time fully. SWH has been effectively predicted using LSTM. However, one notable drawback of LSTM is that it requires many parameters for training. As a result, the training procedure is time-intensive and prone to overfitting.

Choi et al. [Choi et al., (2020)] proposed using deep neural network-based algorithms to estimate extreme wave heights in real-time from raw marine images. First, the authors calculated the appropriate wave height level using a single ocean picture. A classification model is built depending on CNN. Second, the authors proposed using a regression model to estimate significant wave heights from many marine images. This technique extracts Spatio-temporal information from time-series pictures using convolutional LSTM. Quach and colleagues [Quach et al., (2020)] Predicted SWH by extracting data from Synthetic Aperture Radar (SAR) images using a CNN. When compared to earlier efforts, their DL-based solution performed much better. This achievement established the viability and efficacy of deep convolutional techniques for the Sea Wave Height forecast. Gao et al. [Gao et al., (2021)] studied unique operational wave forecasting methods in the Bohai Sea, building wave height prediction models for three places. Using training samples of sea level wind and wave heights, this method is developed on a long short-term memory (LSTM) neural network.

As a result, the literature mentioned above studies have various limitations, and to overcome the constraints in existing works, a novel technique is required. As a result, our research provides a novel network that can accurately forecast wave heights, as discussed in the next phase.

3. Intelligent ocean wave height prediction system using light GBM model

Marine disasters cause serious damage to many countries worldwide, resulting in thousands of casualties and significant economic losses. Ships and marine or coastal infrastructure can be destroyed by ocean tides with a high Significant Wave Height. It is critical to anticipate sea wave heights rapidly and exactly in disaster warning and emergency preparedness and the construction and preservation of seaside and offshore infrastructure, marine transport, and ecological security. The existing research employs traditional empirical or numerical-based forecasting models to detect wave height, but it is complex and inaccurate; hence, our research introduces the light GBM, which predicts wave height over a half-hour period using a tree-based machine learning method. To filter out data instances and generate a split value, light GBM employs a design known as Gradient-based One-Side Sampling (GOSS).

We used wave speed, peak wave direction, zero up crossing wave period, wave period, and SWH as inputs. The light GBM model, over other soft computing models, enables us to input many features. All wave variables were used to train the model, including wave period and peak wave direction. Three new features, comprising considerable wave height data, were generated before training, including wavelength, wave number, and sea surface temperature. Before training the model, the current wave height column was removed from the data frame to avoid loss. Fig. 1 depicts the framework of the proposed method.

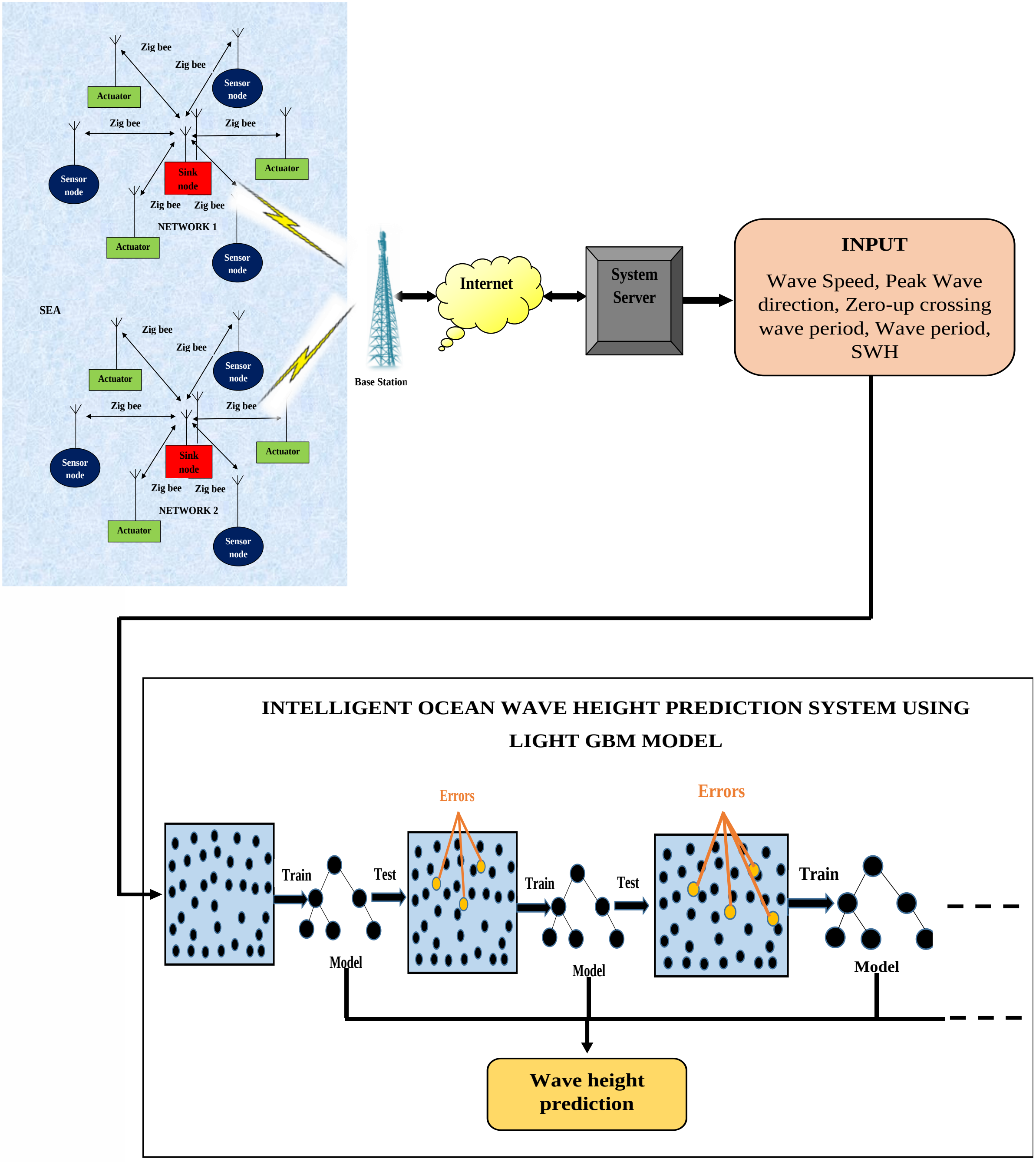

Fig. 1. Structure of the proposed method

3.1 Dataset description

This research collected the data from Coastal Data System – Waves (Mooloolaba) [26], in which wave characteristics were measured and calculated using data acquired by a Mooloolaba-based wave monitoring buoy. It is used to calculate sea levels, direction, and period. The motion (or heave) of a wave monitoring buoy as it drifts up and down with each incoming wave is monitored and processed electronically. The information recorded by the wave monitoring buoys is transmitted via radio signal to a nearby receiving station. The wave data is stored, analyzed, and summarized by a computer connected to the radio receiver. Wave monitoring station data is retrieved each hour, and fresh wave charts are posted to the web every 20 minutes. From 2017 until the present, we acquired 43729 data points, 70 percent of which were utilized for training and 30 percent for testing. Significant wave height (H_s), maximum wave height (H_{max}), zero-up crossing wave period (T_z), peak energy wave period (T_P), peak direction, and Sea surface temperature are the variables in the gathered datasets (SST).

Table 1. Properties of various features used in this dataset [26]

Variables	Minimum	Maximum	Average	Standard Deviation δ
Significant wave height (H_s)	0.294	4.257	1.238	0.53
Maximum wave height (H_{max})	0.51	7.906	2.09	0.897
Zero up-crossing wave period (T_z)	3.076	10.92	5.617	0.928
Peak energy wave period (T_P)	2.72	21.12	9.00	2.39
Peak direction	5	358	98.63	24.28
Sea Surface Temperature (SST)	19.8	28.65	23.95	2.23

From table 1, the variables extracted from the Mooloolaba dataset, such as H_s, H_{max}, T_z, T_P, peak direction and SST values are plotted in the following fig. 2.

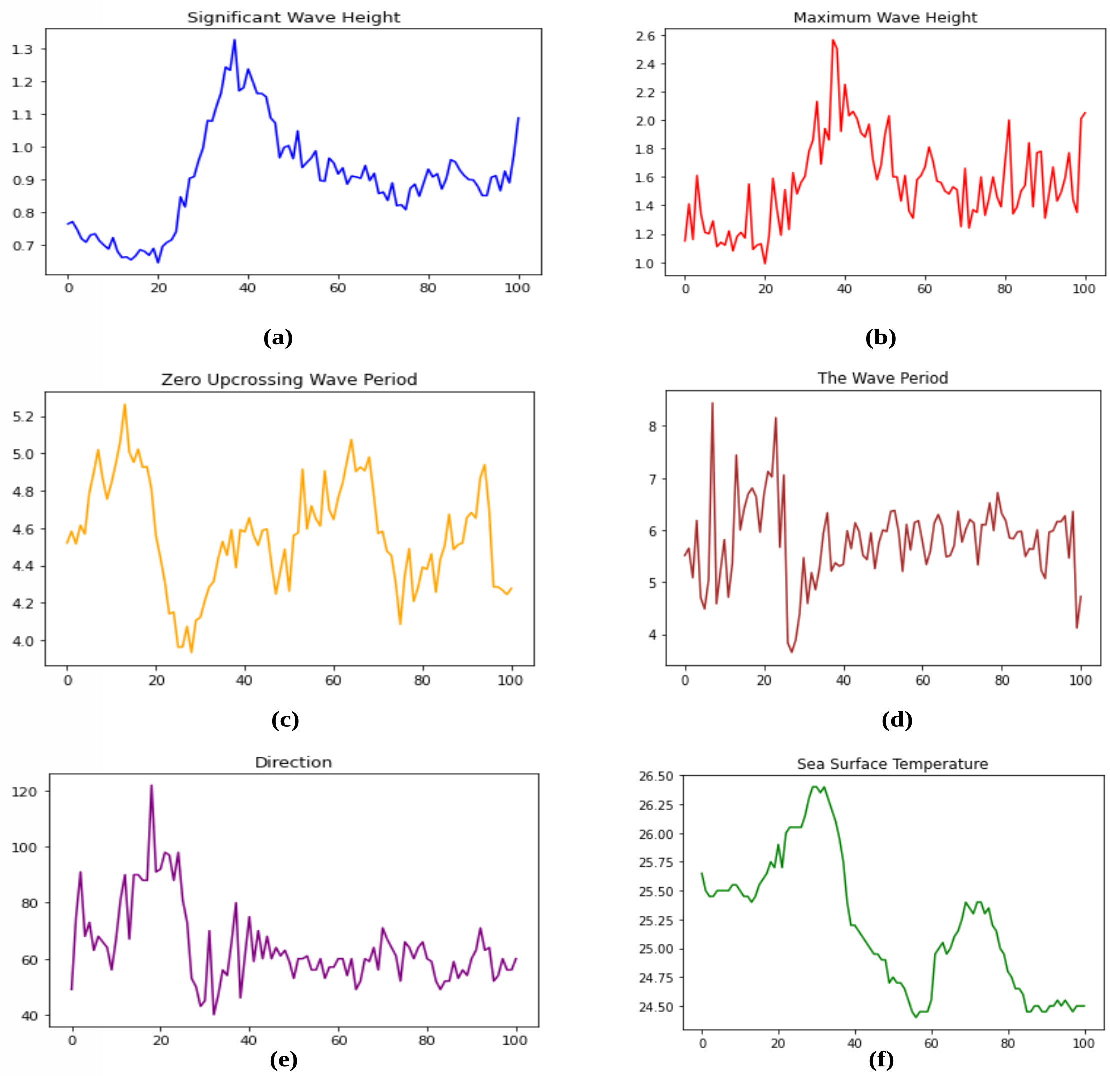

Fig. 2. Variables extracted from the dataset [26]

In fig. 2(a), H_s represents the significant wave height; while analyzing a wave record, the highest one-third of the wave heights in the record is taken into account. Fig. 2(b) shows that the maximum sea level (H_{max}), is the height of the highest single wave. Fig. 2(c) depicts the zero up-crossing wave period (T_z), which is the average of a wave record's zero-up crossing wave periods. Fig. 2(d) illustrates the peak energy wave period (T_P), which is the period of the waves that produce highest energy. Fig. 2(e) shows the peak direction, which is the angle measured in degrees from true north from which the largest waves are flowing.

The Sea Surface Temperature (SST) is measured in degrees Celsius by a wave measurement buoy, as shown in fig. 2(f). Furthermore, the wave speed (C) is calculated based on the following stated formulas:

Wavelength (L) = $gT^2/_{2\pi}$

Wave Number (k) = $2\pi/_L$

Angular Frequency (ω) = $2\pi/_{T_P}$

Wave Speed (C) = $\omega/_k$ (1)

The other factors are the hour of the day, the day of the month, and the month of the year. As a consequence, in this study, the wave frequency, peak wave direction, zero up crossing wave period, wave period, and SWH were employed as inputs. These values are then passed to the light GBM, which will be discussed in further detail in the following section.

3.2 Proposed light gradient boosting machine (lgbm) approach for wave height prediction

Traditional empirical or numerical-based forecasting models are used in existing research. However, they are slow and inaccurate. Our research uses light GBM, a tree-based machine-learning algorithm, to accurately estimate wave height with minimum training time. light GBM is an ensemble technique that uses Decision Trees (DT), which perform data trapping and improving. Trapping and improving are two common statistical techniques for increased accuracy.

Furthermore, light GBM employs the forward distributing technique. The residue is matched by a negative slope in each iteration of learning a decision tree. First, prepare the training dataset as $D_z = \{(x_{zi}, y_{zi})\}_{i=1}^{n_z}, x_{zi} \in R_z^{m_z+1}, y_{zi} \in R_z$, where n_z is the number of samples. $x_{zi}(i = 1,2 \dots n_z)$ is m_z dimensional input vector and $m_z = N_{zw_z} \times N_{zf_z} + C$, where N_{zw_z} is the size of the time frame, N_{zf_z} is a number of characteristics that have been chosen, C is the wave speed. $y_{zi}(i = 1,2 \dots n_z)$ is one of the dimensional wave height predictions is presented in fig. 3.

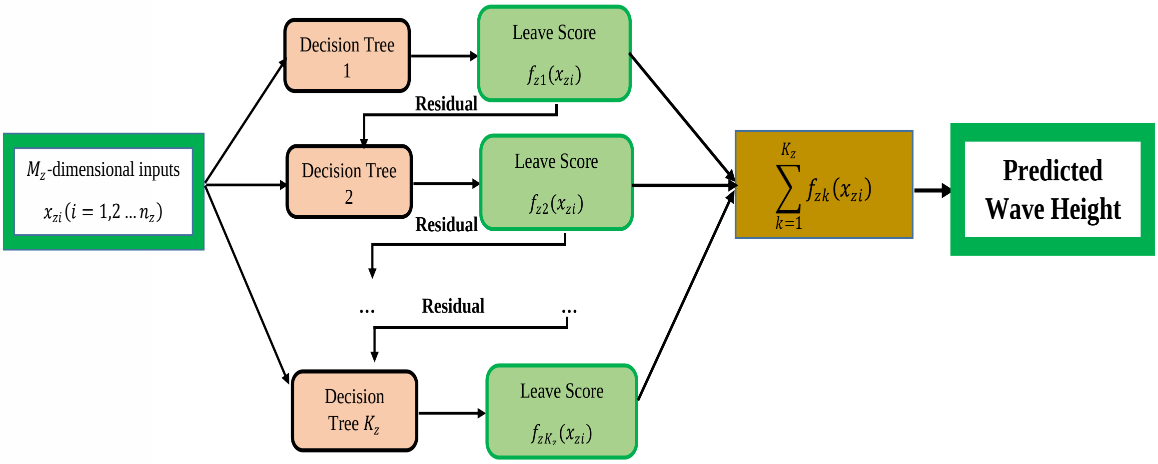

Fig. 3. Light GBM structure for wave height prediction

The height of the waves is calculated by aggregating the prediction of each tree in a group of trees:

$$\widehat{y_{zi}} = \sum_{k=1}^{K_z} f_{zk}(x_{zi}), f_{zk} \in F_z \quad (2)$$

where K_z is the total number of trees, F_z is a space containing all potential tree structures, and f_{zk} is one of the trees with leaf scores. By decreasing the objective, f_{zk} is obtained:

$$f_{zk} = \arg\min_{f_{zk}} \sum_{i=1}^{n_z} L_z(y_{zi}, \widehat{y_{zi}}^{(k)}) + \Omega(f_{zk}) \quad (3)$$

Where L_z is the loss function for training and Ω is the regularisation purpose, generally taken by the equation (4):

$$\Omega(f_{zk}) = \gamma T_z + \frac{1}{2}\lambda \sum_{j=1}^{T_z} \omega_j^2 \quad (4)$$

Where γ is the penalty parameter for the number of leaves T_z, and ω is the leaves' weights. When L_z employs a squared error loss function, the loss becomes:

$$L_z\left(y_z, \widehat{y_z}^{(k-1)} + f_{zk}(x_z)\right) = \left[y_z - \widehat{y_z}^{(k-1)} - f_{zk}(x_z)\right]^2 \quad (5)$$

$$= [r_z - f_{zk}(x_z)]^2$$

f_{zk} is obtained using residual fitting r_z. Using a quadratic approximation, at round k, we can define the function to minimize as:

$$f_{zk} \simeq \arg\min_{f_{zk}} \sum_{i=1}^{n_z} [g_{zi}, f_{zk}(x_{zi}) + \frac{1}{2} h_{zi} f_{zk}^2(x_{zi})] + \Omega(f_{zk}) \quad (6)$$

Where $g_{zi} = \partial_{\hat{y}_{z(k-1)}} L_z(y_{zi}, \widehat{y_z}^{(k-1)}), h_{zi} = \partial^2_{\hat{y}_{z(k-1)}} L_z(y_{zi}, \widehat{y_z}^{(k-1)})$. As a consequence, minimizing this objective function generates a new tree. Furthermore, the decision tree divides each node based on how it acquires information. Eq. (7) gives the variance gain of splitting feature j at location d_z for a node:

$$V_{zj\backslash O_Z}(d_z) = \frac{1}{n_{O_Z}}\left\{\frac{\left(\sum\{x_{zi}\in O_Z: x_{zij}\le d_z\} g_{zi}\right)^2}{n^j_{zl\backslash O_Z}(d_z)} + \frac{\left(\sum\{x_{zi}\in O_Z: x_{zij}> d_z\} g_{zi}\right)^2}{n^j_{r_z\backslash O_Z}(d_z)}\right\} \quad (7)$$

where O_Z is the number of samples on a fixed decision tree node,

$n_{O_Z} = \sum I_z[x_{zi} \in O_Z]$, $n^j_{zl\backslash O_Z}(d_z) = \sum I_z[x_{zi} \in O_Z: x_{zij} \le d_z]$, $n^j_{r_z\backslash O_Z}(d_z) = \sum I_z[x_{zi} \in O_Z: x_{zij} > d_z]$.

All samples must be scanned to select the optimum partition point to calculate the information gain. When dealing with samples with enormous numbers and dimensions derived from significant wave height, efficacy and accuracy are challenging to achieve. Light GBM employs the Gradient-based One-Side Sampling (GOSS) approach to reduce the quantity of training information generated when a node divides, as shown in Eq. (7). To avoid loss, the current wave height column was deleted from the data frame before training the model.

$$V_{zj}(d_z) = \frac{1}{n_{O_Z}}\left\{\frac{\left(\sum_{x_{zi}\in A_{zl}} g_{zi} + \frac{1-a}{b}\sum_{x_{zi}\in B_{zl}} g_{zi}\right)^2}{n^j_{zl}(d_z)} + \frac{\left(\sum_{x_{zi}\in A_{zr_z}} g_{zi} + \frac{1-a}{b}\sum_{x_{zi}\in B_{zr_z}} g_{zi}\right)^2}{n^j_{r_z}(d_z)}\right\} \quad (8)$$

where A_z is a subset of the top a×100% examples with greater inclines, and B_z is a subset randomly selected from the outstanding set of (1-a) ×100% instances with lesser gradients. $A_{zl} = \{x_{zi} \in A_z: x_{zij} \le d_z\}$, $A_{zr_z} = \{x_{zi} \in A_z: x_{zij} > d_z\}$, $B_{zl} = \{x_{zi} \in B_z: x_{zij} \le d_z\}$, $B_{zr_z} = \{x_{zi} \in B_z: x_{zij} > d_z\}$.

The GOSS approach determines the split point by computing the $V_{zj}(d_z)$ rather than all occurrences, with a narrower sample of instances, reducing computing load and increasing noise signal redundancy. The following figure 4 provides the overall flowchart of the proposed light GBM approach.

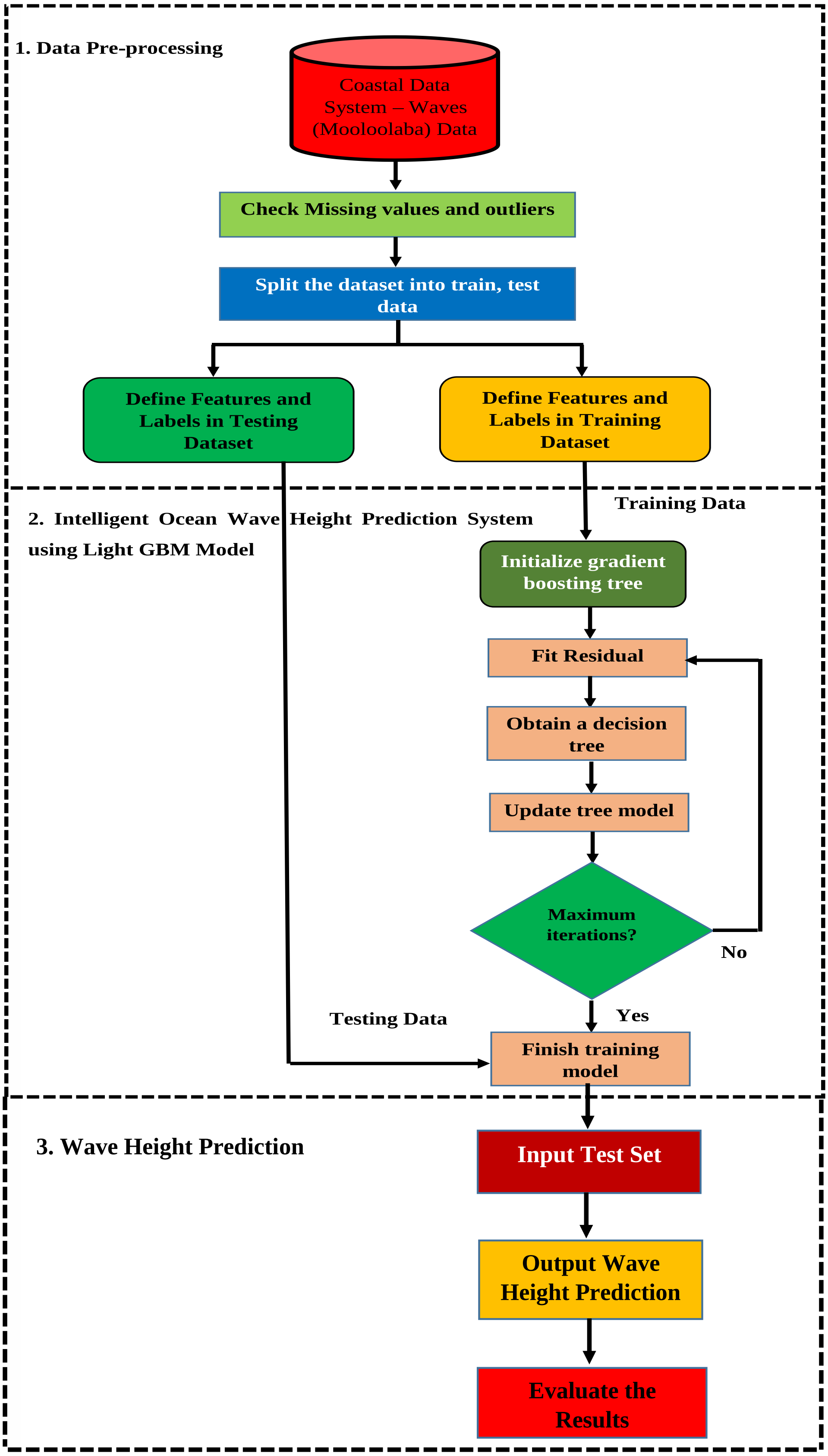

Fig. 4. Flowchart of the proposed approach

As a result, this research attains higher accuracy. Moreover, the following section discusses the performance and comparison results of the proposed method.

4. Result and discussion

This sector details the proposed approach's implementation outcomes, as well as its performance and comparative findings.

Tool : PYTHON 3
OS : Windows 7 (64 bit)
Processor : Intel Premium
RAM :8GB RAM

4.1 Performance parameters

The performance parameters of the proposed Light Gradient Boosting Machine technique are explained in this section.

4.1.1 Training and validation accuracy

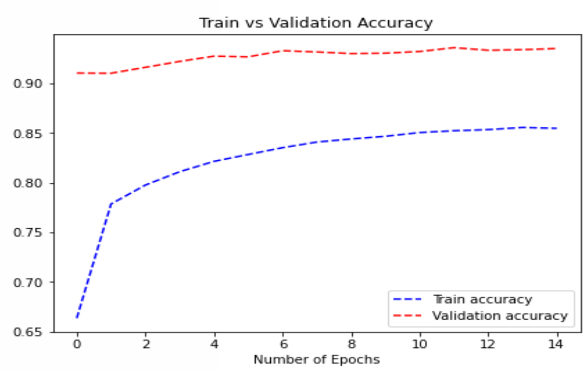

Fig. 5. Accuracy in training and validation

From fig. 5, Accuracy in Training and Validation are 0.83 and 0.926 at epoch 14. As a result, the validation accuracy is greater than the training accuracy by using our proposed light GBM approach, which shows the effectiveness of the proposed approach.

4.1.2 Training and validation loss

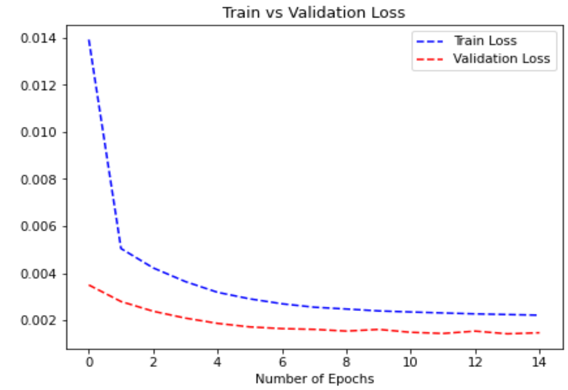

Fig. 6. Loss of training and validation

The training and validation loss is 0.0032 and 0.002 at epoch 14, respectively. From fig. 6, the validation loss is lesser than the training loss by using our proposed light gradient boosting machine approach.

4.1.3 Significant wave height (H_s) prediction

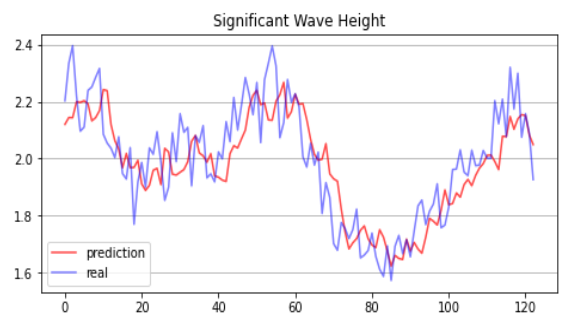

Fig. 7. Substantial wave height (H_s) prediction

Fig. 7 illustrates the major wave height prediction findings. This substantial wave height (H_s) is predicted by using our proposed machine learning light gradient boosting machine approach. The anticipated wave height is substantially comparable to the actual significant wave height, demonstrating the efficacy of the proposed technique.

4.1.4 Root mean square error (RMSE) analysis

To assess the presentation of our method, we use measures such as Root Mean Squared Error (RMSE).

Root Mean Square Error (RMSE)

To obtain the Root Mean square error, compute the residual (the difference among prediction and reality) for every portion of information, the norms of the residual for each piece of data, the average of residuals, and the square root of that mean. RMSE is widely used in supervised training systems since it utilizes and needs real observations at each projected data point. The square error is determined using the following formula:

$$\text{RMSE}=\sqrt{\frac{\sum_{i=1}^{N_z}(x_{zi}-\widehat{x_{zi}})^2}{N_z}} \quad (9)$$

Where, x_{zi} are temporal sequence of genuine observations, $\widehat{x_{zi}}$ is the time series estimation, N_z is the number of missing points.

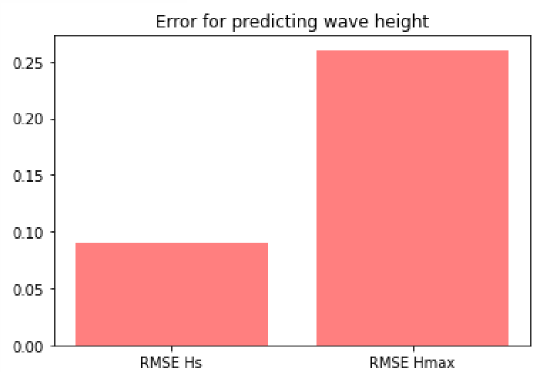

Fig. 8. RMSE for $\boldsymbol{H_s}$ and $\boldsymbol{H_{max}}$

Fig. 8 illustrates the RMSE for the significant wave height and maximum tallness. The obtained RMSE values of H_s, H_{max} are 0.092 and 0.262, respectively, by using our proposed light GBM approach.

4.2 Comparison analysis

This section compares the proposed approach to other current techniques. In terms of NMSE, MSE, MAPE, and R values, the developed model's forecasting performance is compared to that of ANN models such as Multilayer Perceptron's Neural Network (MPNN) [Elbisy & Elbisy, (2021)], Cascade Correlation Neural Network (CCNN) [Elbisy & Elbisy, (2021)] Radial Basis Function Neural Network (RBFNN) [Elbisy & Elbisy, (2021)] and General Regression Neural Network (GRNN) [Elbisy & Elbisy, (2021)].

4.2.1 Comparison of normalized mean squared error

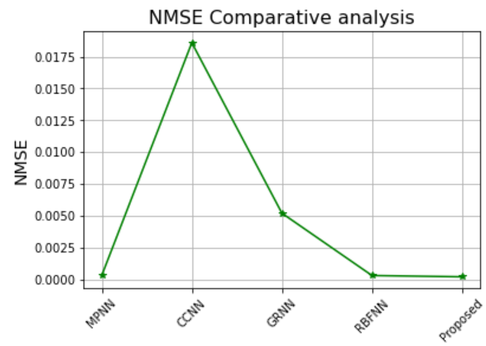

Fig. 9. Comparison of normalized mean squared error

The overall Normalized Mean Squared Error comparison is shown in Fig. 9. The NMSE of the proposed technique improves by using light GBM. Our proposed approach attains lesser error when compared to the baseline as Multilayer Perceptron Neural Network (MPNN) [Elbisy & Elbisy, (2021)], Cascade Correlation Neural Network (CCNN) [Elbisy & Elbisy, (2021)], General Regression Neural Network (GRNN) [Elbisy & Elbisy, (2021)], and Radial Basis Function Neural Network (RBFNN) [Elbisy & Elbisy, (2021)] such as 0.0003, 0.0186, 0.0052, and 0.0003 respectively. As a result, our novel technique has an error of 0.0002, which is less than baseline approaches.

4.2.2 Comparison of mean squared error

The Mean squared error (MSE) is used to calculate the grade of error in statistical models. It is determined by the average squared difference between detected and predicted principles.

$$\text{MSE} = \frac{1}{n_z}\sum_{i=1}^{n_z}(y_{zi}-\widehat{y_{zi}})^2 \quad (10)$$

Where, n_z is the number of information sets, y_{zi} are the observed values, $\widehat{y_{zi}}$ is the forecasted value.

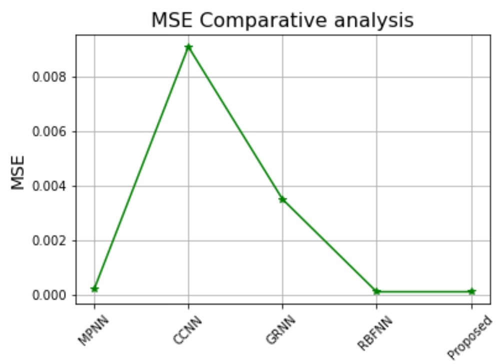

Fig. 10. Comparison of mean squared error (MSE)

The overall MSE comparison is shown in Fig. 10. The MSE of the proposed technique improves by using light GBM. Our proposed approach attains lesser error when compared to the baseline as Multilayer Perceptron Neural Network (MPNN) [Elbisy & Elbisy, (2021)], Cascade Correlation Neural Network (CCNN) [Elbisy & Elbisy, (2021)], General Regression Neural Network (GRNN) [Elbisy & Elbisy, (2021)], and Radial Basis Function Neural Network (RBFNN) [Elbisy & Elbisy, (2021)] such as 0.0002, 0.0091, 0.0035, and 0.0001 respectively. As a result, our novel technique has an MSE of 0.0001, which is less than the baseline approaches.

4.2.3 Comparison of mean absolute percentage error (MAPE)

The Mean absolute percentage error (MAPE) of a predicting system is used to assess its accuracy. It computes the average absolute percentage inaccuracy of each entry in a dataset to determine how close the predicted quantities were to the actual amounts.

$$\text{MAPE}\ (\%) = \frac{1}{n_z}\sum_{t=1}^{n_z}\left|\frac{A_{zt}-F_{zt}}{A_{zt}}\right| \tag{11}$$

Where, n_z is the number of times the summation is iterated, A_{zt} is the real rate, F_{zt} is the forecasted rate.

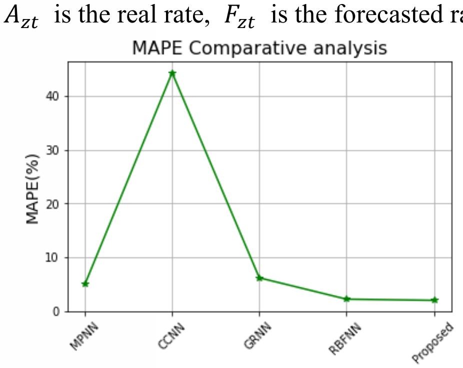

Fig. 11. Comparison of MAPE

The overall Mean Absolute Percentage Error comparison is shown in Fig. 11. The MAPE of the proposed technique improves by using light GBM. Our proposed approach attains lesser error when compared to the baseline as Multilayer Perceptron Neural Network (MPNN) [Elbisy & Elbisy, (2021)], Cascade Correlation Neural Network (CCNN) [Elbisy & Elbisy, (2021)], General Regression Neural Network (GRNN) [Elbisy & Elbisy, (2021)], and Radial Basis Function Neural Network (RBFNN) [Elbisy & Elbisy, (2021)] such as 5.01%, 44.33%, 6.22%, and 2.23%. As a result, our novel technique has a MAPE of 2.21%, which is less than the baseline approaches.

4.2.4 Comparison of correlation coefficient (R)

The correlation coefficient is formulated as follows:

$$R = \frac{\sum_{i=1}^{N_z}(P_{zi}-\overline{P_{zi}})(O_{zi}-\overline{O_{zi}})}{\sqrt{\sum_{i=1}^{N_z}(P_{zi}-\overline{P_{zi}})^2\sum_{i=1}^{N_z}(O_{zi}-\overline{O_{zi}})^2}}$$

Where, $O_{zi}, P_{zi}, N_z, \overline{O_{zi}}$ and $\overline{P_{zi}}$ indicates the observed value, the forecasted rate, the observed number, the detected mean rate, and the forecast mean rate, in that order.

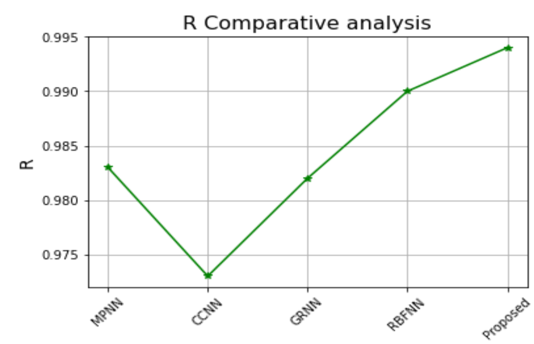

Fig. 12. Comparison of correlation coefficient (R)

The overall R comparison is shown in Fig. 12. The R-value of the proposed technique improves by using light GBM. Our proposed approach attains a higher R-value when compared to the baseline like Multilayer Perceptron Neural Network (MPNN) [Elbisy & Elbisy, (2021)], Cascade Correlation Neural Network (CCNN) [Elbisy & Elbisy, (2021)], General Regression Neural Network (GRNN) [Elbisy & Elbisy, (2021)], and Radial Basis Function Neural Network (RBFNN) [Elbisy & Elbisy, (2021)] such as 0.983, 0.973, 0.982, and 0.99 respectively. As a result, our novel technique has a Correlation Coefficient of 0.994, which is higher than baseline approaches.

As a result, the error such as RMSE, NMSE, MSE, and MAPE values obtained by using our proposed approach as 0.092, 0.0002, 0.0001, and 2.21 respectively, which is outperformed when compared to the existing techniques. Also, the accuracy is high while there are less errors.

5. Conclusion

The LightGBM approach is proposed in this research for predicting sea wave height. The proposed approach is validated using the Mooloolaba Coastal Wave dataset. Processing of data, feature selection, and time window processing all contributed to strong performance on both the training and testing datasets. In comparison to earlier ensemble approaches and neural networks, the proposed method achieves high accuracy and efficiency due to low error, and the prediction becomes increasingly accurate. Finally, the developed method attains less error when compared to findings obtained by existing state-of-the-art approaches. Additionally, we observe that the numerical model's forecast of wave height sometimes lags. The predictions may not come true because our model only considers the significant wave height as an input. In further study, we will incorporate sea surface wind, atmospheric pressure, and other variables as input and influences to examine the effects of the wave type and meteorological components. To improve accuracy, deep learning or other optimization algorithms might be examined in future.

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