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Development of IIOT-Based Pd-Maas Using RNN-LSTM Model with Jelly Fish Optimization in the Indian Ship Building Industry

PNV Srinivasa Rao*, ***PVY Jayasree***

Department of EECE, GITAM Institute of Technology, GITAM University, Visakhapatnam, India.
*Corresponding Author.

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Abstract

Building and repair of ships are considered the Evergreen industry nationally as well as globally. The ships are generally gone in by the periodic scheduled repairs by the Indian shipbuilding industries. Sometimes industries lack productivity and lack of modernization some modern methods should be followed. The study focuses on the optimization of predictive maintenance as a service on the industrial Internet of Things by machine learning algorithms. The main contribution of the study is the use of optimization techniques for feature selection and RNN-LSTM for improved accuracy. The selected data set is pre-processed and feature selection for the optimization for the improvement in accuracy, and automation decision making the framework of the convolution neural network along with the ensemble boosted tree classifier developed is optimized using the jellyfish optimization and Recurrent Neural Network and Long Short-Term Memory (RNN-LSTM) model for the recognition of patterns and numerical vectors in the real-world data after processing of output then it is sent back as the input for the recurrent network to make the decision in the shipbuilding process. By evaluating the performance results and confusion matrix through the training and testing output all the metrics for training and testing are classified in the confusion matrix. Our proposed predictive maintenance model with high accuracy for the detection of failures in earlier stages and maintenance of Indian ships can help in the avoidance of accidents in voyages and the loss of goods and money during transportation. The validation of the proposed predictive maintenance model optimization with different types of deep learning algorithms shows that our proposed methodology gives an improved accuracy of 98.9336% which is higher than any other models. The proposed Pd-MaaS helps in early detection of failures in the ships which is the greatest advantage in the Indian shipbuilding industry.

Keywords: Indian Shipbuilding, Jellyfish Optimization, Machine Learning, Predictive Maintenance as a Service, RNN-LSTM.

Introduction

The shipping industry provides the shipbuilding industry with business prospects. The majority of commercial shipyards' customers are shipping corporations. As a result, the economic and growth prospects of the shipping industry have a significant impact on the fortunes of the shipbuilding industry. The shipbuilding industry is significantly impacted by the supply and demand conditions in the shipping sector. For the delivery of a new ship, the lead time ranges from one to three years. In preparation for the ship's potential future use, orders are placed. Many times, businesses even sign into a charter agreement in advance, which makes the shipyard's ability to produce within agreed-upon timeframes very necessary.

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Background

India is the sixteenth-largest maritime nation in the world, having a 7,517-kilometer coastline. According to the Ministry of Shipping, 12 major ports and 200 recognized minor and intermediate ports handle around 95% of India's trading by volume and 70% by value. The expansion of global trade and the lifting of trade restrictions have caused developing nations to focus more on improving their infrastructure, such as their roads, airports, and seaports, which were critical to the growth of their economies. The ability to move huge shipments and all of these factors have given the shipping sector a significant competitive advantage. Over time, a number of additional facets of shipping have emerged, including containerization, multimodal transport services, advancements in maritime engineering technology, and so forth. The government, together with other public and private businesses, has made various initiatives to boost shipping in the nation. The majority of Asian nations are at the top of the list of emerging nations that have experienced growth in recent years at various levels to boost their economies[1].

In the maritime industry, due to the correction and prevent it to management mechanical systems that include equipment, machinery, and plants are the system which is upgraded and changed at a specific interval of time. Marine predictive maintenance parts can need to be changed while they are still in use during their planned or regular service intervals, which would be expensive. Finally, the component of the system might have outlived its usefulness earlier than expected. The longevity, safety, and maintainability of maritime mechanical components can no longer be improved by using more conventional maintenance techniques. The gaps left by conventional maintenance could be filled by predictive maintenance. With the help of machine learning and deep learning techniques and sensor technologies in the platform of the industrial Internet of Things, it is possible to optimize the maintenance of the mechanical systems in the maritime industry.

Optimization is the technique that obtains response over opinions and parameters for the functions resulting in the least or maximum output in the function. Variable act as input for fitness function, goal function, and cost function, and the outcome can take the shape of money or physical substance. Numerous approaches can be used to tackle optimization problems. These strategies were developed in response to natural processes. These methods frequently begin with a modest number of variables and increase their number until they reach the minimum and maximum goal of the function. In recent days, Metaheuristic optimization algorithms have been widely used because they are effective at solving challenging issues. This is used in various fields because the principles and solutions to these problems are straightforward. These techniques can prevent local minima and don't need to be aware of the gradient of the objective function. They are used in a variety of industries to address a wide range of problems. A metaheuristic algorithm relies on computers to function. Because of this, improvements in computer processing power have made it possible to create metaheuristic algorithms[2].

The supply bases for the shipbuilding sector have moved to less expensive regions. The prominence of new nations has increased during economic booms. India's availability of materials and low labor costs allow it to compete with the rest of the world in shipbuilding. The majority of Indian shipbuilding is done in shipyards, which are operated by the federal and state governments in both the public and private sectors. With the use of IoT, shipping companies may now get massive amounts of data about shipbuilding equipment along a route. These data can be used to improve the efficiency and development of ship operations and maintenance[3].

There are a number of significant problems and challenges in the context of the ongoing work on the application of IoT in the Jellyfish Algorithm for predictive maintenance in the Indian Ship Building Industry:

- Strong data integration solutions are needed when combining data from diverse ship systems, legacy equipment, and sensor types because this can be a challenging task.
- It might be difficult to make sure that the data gathered for predictive maintenance is reliable and consistent across various sensors and systems. Inaccurate data may result in inaccurate alerts or neglected maintenance requirements.
- Marine settings that are harsh might endanger sensors and monitoring devices, possibly resulting in early failures and decreased reliability.

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To overcome these challenges IoT device is used for collecting data from the different components of the Ship to detect proactive repairs and the parts require maintenance. Jellyfish optimization is used for predictive maintenance and RNN-LSTM is used for increased accuracy and reliability

Challenges

In the administration of the maritime industry in India, the prevention and maintenance administration in the mechanical systems, which includes devices, machines, and industrial plants, can be modified during the fine intervals. The predictive maintenance service offers replacement of the parts which is functioning, but it requires some regular maintenance with schedules for cutting down the expenses. Since the components of predictive maintenance are more useful. It leads to the traditional model for preserving the marine engine systems for improving their security and maintenance. By utilizing machine learning techniques like convolution neural networks in the industrial Internet of Things for optimizing the maintenance of mechanical devices, the literature review reveals that most of the predictive maintenance is artificial intelligence based on the streaming of data and early detection of failures.

Motivation

Technology from the Industrial Internet of Things (IIoT) is increasingly utilized in the maritime sector. The marine industry is only beginning to adopt IoT technologies. Each IoT technology has a diverse set of capabilities and possible uses. As a result, useful use case scenarios have been created. Because there are so many alternatives, IoT decision-making necessitates a wide variety of knowledge. Additionally, a variety of systems may be impacted by the adoption of IoT. Examining all of the intricate ship systems at once is crucial when it comes to IoT integration. It depends on the end-user industries because it is an intermediary firm. Shipbuilding investments can be profitable for the fabrication of steel, technical products, and consumables. Such a sizable investment has profound repercussions on other industrial industries in addition to generating employment and promoting investment elsewhere.

Research Problem

The problem of the research study is given below;

- What is the role of Jellyfish optimization algorithm in the research study?
- Why Predictive maintenance is required in the Indian shipbuilding industry?
- What is the accuracy and reliability of the proposed model in fault detection in Ships?

Research Objectives

The main objectives of the study are given below

- Predictive maintenance as a service model based on the Industrial Internet of Things is developed for making analysis based on prediction
- Model is optimized for output using CNN with ensemble boosted classifier
- The generated output is collected, and the data is pre-processed. Using Jellyfish Optimization, feature selection is made for the removal of irrelevant features.
- The model is trained validated, and optimized using RNN-LSTM, which helps in the early detection of failures during processing and maintenance.

Contributions

- The research framework shows the right progressing path for the development of research in the correct method.
- The main contribution of the study is the use of optimization techniques for feature selection and RNN-LSTM for improved accuracy.
- The optimization technique used for the optimization of predictive maintenance as a service based on the industrial Internet of Things using jellyfish optimization for feature selection.

Applications and functionalities of IoT in Jelly Fish Algorithm

- IoT devices collect data from different components of a ship like control system, sensors and engines and anticipate when maintenance is required by reducing downtime and proactive repairs
- It allows remote monitoring of the performance and condition of ship components to ensure safety and optimal operation

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- It helps in reducing cost maintenance through prevention of breakdowns

The introduction part of the study includes background information about the Indian shipbuilding industry research objectives and limitations. The second part includes a literature review for analysis and reveals different types of research work related to our study. The third part includes the methodology of the proposed optimization framework on the fourth part includes results and discussion. The fifth part deals with the validation of the proposed model with other deep-learning techniques for evaluating our findings.

Literature Review

India has had a boom in maritime trade and shipbuilding since the Indus Valley civilization. Of these, shipbuilding evolved more as an art than a science in India and has so largely gone unrecorded. Through instruction and practical experience, the art has been passed down from one generation to the next. Bombay wasn't a major metropolis or a commerce hub when the Europeans first arrived in India. The Parsis were then mostly in charge of shipbuilding from Surat, but the English found it challenging to have their vessels built here because of the Portuguese's monopolistic grip. Once the English took over Bombay, they concentrated on making it a trading and shipbuilding hub but found the process to be cumbersome. They worked very hard to recruit a Parsi shipbuilder, or "Wadia" (shipbuilder in Gujarati), who brought shipbuilding to Bombay and helped the Bombay Dockyard carry on India's shipbuilding tradition[4]. Reported currently in the early stages of the fourth industrial revolution, which is often referred to by terms like industry, smart factories, the Internet of Things (IOT) [5] cyber-physical systems, and digital transformation. Vertical and horizontal value chains can be digitalized, new products and services can be developed, and new business models can be developed as part of Industry 4.0. The enhancement of the customer experience, increased marketing efficiency, and cost savings are some of the primary operational drivers of the change. Predictive maintenance is a key component of the smart factory in this study, where maximizing uptime and ensuring high production facility availability are key objectives.

The fourth industrial revolution has spawned a number of ideas that have developed concurrently. One of these ideas is predictive maintenance, which plays a major role in the sustainable production and manufacturing system for the introduction of digital versions in machine maintenance. The total amount of data derived from the manufacturing process has grown tremendously as a result of the spread of sensor technology. Maintenance 4.0 continues to be a strong point for the businesses that are employed despite the financial organizational and data sourcing and issues in machine repair. In fact, predictive maintenance enables the reduction of expenses and machine downtime, extending of life of machines and enhancing the quality of production. The method was typically distinguished by the specific workflow design, which begins with the project comprehension and gathering of data, and concludes with making decisions in that particular stage. The categorizing and identification of the life cycle in the project maintenance and the difficulties encountered. The research includes the techniques of the tools applied for the intelligent predictive maintenance models in industry 4.0. The model is presented as associated with the maintenance type, which includes remaining useful life, prognostics, and health management, and condition-based maintenance. The decision-making in the support face is the suggestion for a platform for predictive maintenance, and the model is applied in the industrial maintenance process. In the framework of smart maintenance, this platform ensures administration and constant data transfer among equipment throughout their entire cycle[6]. The major difficulty in the field includes the foreseeing ability during the maintenance of assets is the most significant thing. Option for predictive maintenance improves the quality of production, control, cost, and machine downtime[7]. The courses and survey on industry 4.0 include machine learning techniques and data analytics for the improvement in practicing production and following up on predictive maintenance structure and techniques. Their research provides the literature analysis which is most comprehensive for projects in Industry 4.0, including predictive maintenance, cataloging techniques, and identifying the applications and norms. The major contribution includes the discussion of existing restrictions and difficulties in the predictive maintenance and taxonomy for the categorizing field on the requirements of Industry

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4.0. The results depict that computer science includes distributed computing as well as artificial intelligence presence of engineering in the present field, which is the dominant area for the expertise for detecting the necessity in the multidisciplinary approach for the effective address of industry 4.0[8].

Dependencies and the possibility of failure-related costs rise as a result. In predictive maintenance as a service within the framework of industry 4.0 supported with standards and architecture, there is, nevertheless, a dearth of research. This thesis examines how Industry 4.0 concepts, designs, and platforms may support data-driven predictive maintenance. The modules of predictive maintenance, which fit in the industrial standard architectural reference model industry, 4.0 model is designed using a flexible predictive maintenance case. The research also examines predictive maintenance as a service and the creation of a virtual factory with a focus on supporting predictive maintenance in addition to looking for predictive maintenance for manufacturing types in particular industries. The research develops the predictive maintenance architecture in Industry 4.0 with an algorithm for predictive maintenance modules and for the estimation of RUL and the maintenance scheduling models for supporting the components and multiple machines by using the design of a science research approach[9]. The term "Internet of Things" refers to a network of various distributed, intelligent, and heterogeneous objects that can be linked together to communicate with one another online (IoT). Additionally, the IoT concept could be used in the industrial setting to improve goods production and service for the reduction of danger in disaster. Happening. Industrial IoT refers to the use of IoT to improve industrial productivity. Emergent configuration is the method that is used for the optimization of communication and interaction among the IoT-connected devices for the increase in effectiveness in the IoT systems that are connected and maximize user satisfaction. The linked devices must work together in an adaptable, interoperable, and homogeneous way to achieve user goals. In addition to an evaluation of IIoT systems, a survey of the IoT concept is offered in this work. In order to increase the throughput of production in oil and gas in the marine ecosystem and buy management of the exploration process that is specified in an emergency situation that includes anthropogenic spillages of oil and gas, the application of computer-aided software defined networking based on EC architecture is proposed Aastha unique model[10].

The volume of the data generated during the operation of the intelligent workshops exhibits the tendency of explosive growth tendency, which is attributed to the technology of the industrial Internet of Things leading to rapid development and implementation. Rapid intelligent decision-making is predicated on the analysis and processing of these inputs in real time. As a result, manufacturing sites typically employ the cloud-edge-terminal (CET) architecture and overall processing time and the data can be decreased by creating an appropriate method for offloading for the computation jobs. The execution of manufacturing jobs typically results in analysis, measurement, decision-making responsibilities, and demand-driven monitoring. There is a close relationship between them, and how production jobs are scheduled heavily influences how quickly computing tasks need to be generated and processed. The balance between the computing and production efficiency on the delay could not be accomplished since the present optimization approaches for the computation and production scheduling which is carried out for the pursuit of research objectives. It uses the maximum production job completion time and the shortest possible total offloading delay time as its two-primary optimization goals[11].

Within the context of CARP, the suggested collaborative channel allocation system notably enhances the reliability of detection, while also alleviating issues related to noise and crowded frequency bands. As a result, it establishes dependable and high-capacity connections for Smart Grid applications based on Cognitive Radio Sensor Networks (CRSNs). Furthermore, in order to accommodate increased data demands and optimize spectrum usage, the proposed multi-hop routing technique identifies a secondary user relay node that possesses ample spectrum information and offers a higher likelihood of successful communication with minimal interference in the network[12].

It is crucial to ensure the quality of service (QoS) standards in the smart grid by effectively monitoring and instantly managing unforeseen alterations in power generation and distribution processes. The dataset consists of readings obtained by IMWSNs while overseeing and controlling events within the smart grid. This study offers a comparison of our novel approach, encompassing channel detection, channel allocation, and packet forwarding algorithms collectively referred to as CARP, with the existing G-RPL and EQSHC strategies in the context of the smart grid[13].

The concept of the smart grid revolutionizes the delivery of power by providing an efficient, sustainable, and cost-effective approach with minimal environmental repercussions, effectively catering to future energy requirements. Nevertheless, overseeing and managing the smart grid in real-time, particularly to ensure a constant, high-quality power supply in smart cities, presents significant challenges. It necessitates a sophisticated communication framework that prioritizes quality of service (QoS) awareness. The research's objective is to introduce an innovative data-collection method within the smart grid, achieved through the utilization of Software-Defined Mobile Sinks (SDMSs) connected to the Internet, in combination with wireless sensor networks (WSNs) [14].

Research Gap

There are some areas that require more research and analysis in the field of predictive maintenance as a service in the Indian shipbuilding sector. The fact that Indian shipyards frequently use older ships and equipment is one of the major study gaps. To extend the lifespan of older ships, research should concentrate on how to combine predictive maintenance technology with legacy systems successfully. In-depth cost-benefit analyses are required to show the predictive maintenance as a service's return on investment in Indian shipyards. This will aid industrialists in the industry in defending the investment.

Materials and Methods

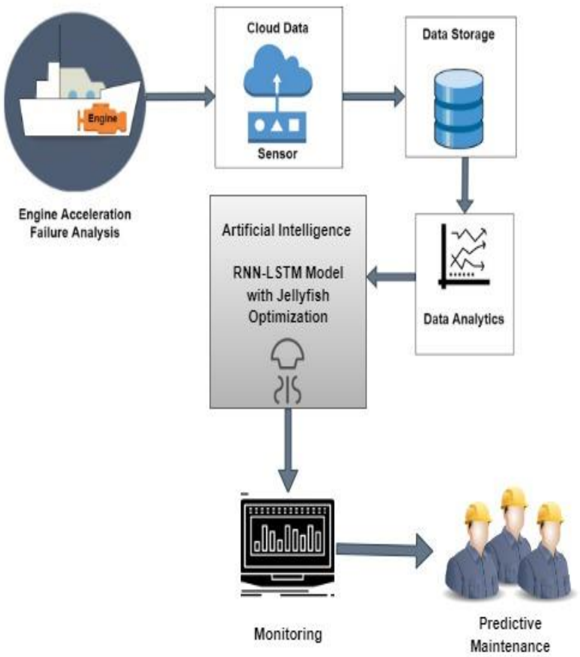

Figure 1. Developing a model of Ship engine failure analysis - Proposed Methodology Pd-MaaS using IIOT (Optimization using RNN-LSTM with Jellyfish Algorithm)

The methodology part includes the optimization of the developed model with the approach of Pd-MaaS based on IIoT by getting the input data for optimization from the output of the prediction model using CNN with an ensemble boosted tree classifier, as shown in Fig 1. The output data is achieved by gradient boosting and an algorithm trained with an ensemble using a decision tree for the prediction model. Using jellyfish optimization, the output data received from the CNN with an ensemble boosted tree classifier is optimized by training and testing of data with RNN-LSTM. The proposed model includes the framework of data transmission in machine learning that includes the pre-processing of the raw data obtained from there sensors of the centralized database. Then the future selection is processed using the jellyfish search optimization algorithm, and the dataset is split for training as well as testing, as shown in Fig 2. The training involves two steps which are training of the data and validation of data. Then the proposed model is increased with accuracy using RNN-LSTM, then the results are obtained. The main goal of the proposed model is to enhance the accuracy of the proposed model generated by CNN with an ensemble boosted tree classifier for analyzing the accuracy of failure in delayed start in the ships and the maintenance of ships. The proposed model is a novelty for failure detection and maintenance in the Indian shipbuilding industry with more accuracy than any other models.

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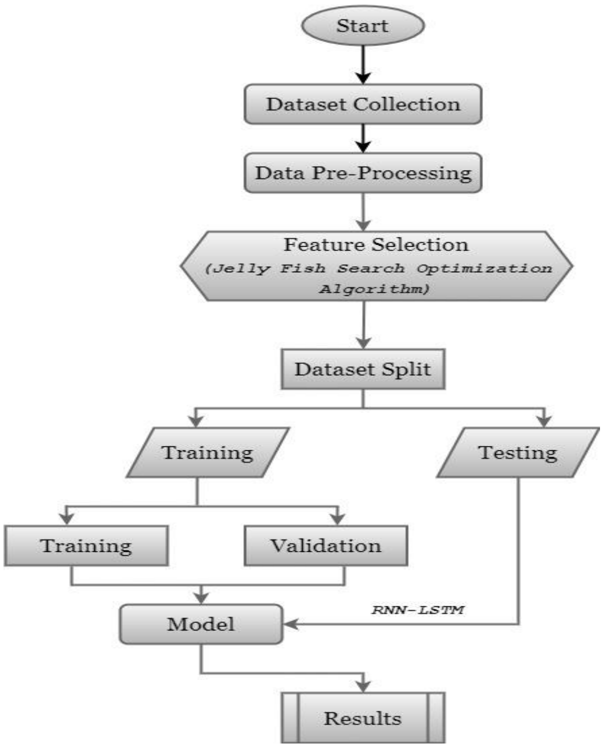

Figure 2. Flowchart for AI and Predictive Analytics – Optimization using RNN-LSTM with Jellyfish Algorithm

Pd-MaaS in Indian Ship Building Industry

In the current scenario of information and advanced technologies using the Internet, Leeds to the emergence of sensing devices, capabilities for controlling, and communication devices for the significant increase in the Internet of Things. It provides a number of solutions in business as well as a technical community, particularly in the manufacturing industries, for implementing and prototyping the solutions using IoT, that leads to the creation of new business models which are characterized by overlapping communities in the shipbuilding industry. The methodological framework includes predictive maintenance as a service model for detecting the failures in the equipment earlier and offers interventions for detecting the pre-failures and Internet services. Thus, predictive maintenance is more helpful in the Indian shipbuilding industry for the detection of failures in the ships before the voyage and during the voyage. Early detection of pre-failures can be carried out to avoid accidents and loss of commodities and ships as well. Ships are considered the major means of transportation among the coastlines in India to import and export goods from one place to another place. The predictive maintenance approach helps in monitoring the data for the prediction of machine conditions in the future and makes the decision based upon the prediction made by it. Internet of Things is applied over predictive maintenance for identification and tracking of the related data and utilization of condition monitoring data and analysis depending upon the machine population. It helps in handling and processing maintenance and production in the shipbuilding industry in the operation phase as well as the maintenance phase.

CNN architecture with Ensemble boosted classifier

Predictive analytics uses artificial intelligence using CNN with ensemble boosted tree classifier for this research study. The gradient boosting algorithm strained the ensemble of the decision tree and was used as the prediction model for this research. The study includes the strategy for breaking up energy area trade-offs and accuracy through the concurrent extracted features. Feature selection is done through 3 layers in the CNN, and it is not pre-processed. The trained and tested feature selection is done through the CNN algorithm, and there obtained results are used for this framework for optimization using jellyfish optimization and RNN-LSTM. Then the feature is incorporated in the ensemble model another time for prediction and classification.

Jellyfish Search Optimization

Feature selection search optimizer for classification. Feature selection enhances the performance of classification by removing irrelevant and redundant features from the collected data set. The main contribution of the feature selection is 2 reduce the training time and increase the accuracy of predictive maintenance and decision-making. Many metaheuristic optimization algorithms are used for the optimization of feature selection processes like genetic algorithm, particle swarm optimization, firebug optimization, and jellyfish optimization. Our research study includes jellyfish optimization for improving the accuracy of feature selection and removal of unnecessary features in the dataset.

RNN-LSTM

A recurrent Neural Network is a continuous flow process of a feed forward neural network which consists of internal memory. The nature of recurrent in RNN helps in performing the same function in

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every input data and the output. The current input is computed, and after processing of output, it is sent back as the current input. This process is discontinuous and helps in making the decision by learning the previous input. It includes recognition of connected handwriting and speech recognition and unsegmented tasks. Every input of RNN is related to each other, so it helps in making decisions accurately. LSTM is the advanced form of RNN with the sequential network for the persistence of the information. The gradient problem has vanished away in RNN- LSTM. LSTM helps in the avoidance of long-term dependency problems. The smart solution for predictive maintenance is used in shipbuilding industries in India to fix the devices before they fail. It works on the mathematical model for prediction of failure time with the connected devices. The optimization of the mathematical model includes a large amount of data for increasing the accuracy of prediction. A large amount of required data can be provided by the industrial Internet of Things in shipbuilding industries. The techniques in machine learning are helpful in producing effective solutions for the production of reminding useful life of devices more accurately. The proposed productive maintenance as a service model based on the industrial Internet of Things uses feature selection with the help of jellyfish optimization and optimize using RNN-LSTM further improve accuracy. The proposed model is connected as a general device along with the central processing unit of the Internet of Things. IoT provides devices with means of communication for transferring data. The collected and pre-processed data is optimized using RNN-LSTM for improved prediction results among the devices for maintenance and production.

The input is fed forwards for learning for retaining the previous information of hidden unit is given in below formula Eq. 1 and Eq. 2

$$h_t = \varphi_h(U_{in}x_t + V_h h_{t-1} + b_h) \;\ldots\ldots\ldots\ldots 1$$

$$y_t = \varphi_y(W_{out}h_t + b_y) \;\ldots\ldots\ldots\ldots 2$$

Where h_{t-1} and $\mathrm{h_t}$ are the vectors of the hidden layers in the current and previous time. φ_y and φ_h are the activation functions for output layer and hidden layer. U_{in} is the weight matrix between the hidden and input layers. W_{out} is the matrix between the output layer and the hidden layer.

RNN-LSTM has the advantage of addressing the data with time series, which helps in the maintenance through prediction analysis since it has the ability to map between the sequences of input and the output with the context information. The work flows between the forget gate, input get, and output get of the LSTM network can be summarized below

$$ft = \varphi a(Wf \times [ht-1, xt] + bf) \;\ldots\ldots..3$$

$$it = \varphi a(Win \times [ht-1, xt] + bin) \;\ldots\ldots.4$$

$$ot = \varphi a(Wout \times [ht-1, xt] + bout) \;\ldots..5$$

Where Wf, Win, $Wout$ are the weight matrix for the forget gate, input gate, and output gate, and bf, bin, $and\ but$ are the bias vectors.

The design of the RNN and LSTM models for the maintenance and decision-making with increased accuracy is given below Eq. 6;

$$\mathrm{y\hat{}RNN - LSTM = \omega RNNy\hat{}RNN + \omega LSTMy\hat{}LSTM} \;\ldots\ldots 6$$

Results

Results of optimization based on predictive maintenance using jellyfish optimization are analyzed and discussed in this part. The output of the predictive maintenance optimization is studied for the outcomes. The best solution obtained from the jellyfish algorithm is shown in Table 1.

Table 1. Training Data for Predictive Maintenance

```
------------------------------------------------------------------------
  Jellyfish Search Optimizer (JS) for mathematical benchmark problems
------------------------------------------------------------------------
The best solution obtained by JS is : -5.096     -4.5602     -3.7562     0.32404     4.4732     -3.8651     -4.2733
The best optimal value of the objective function found by JS is : -3220
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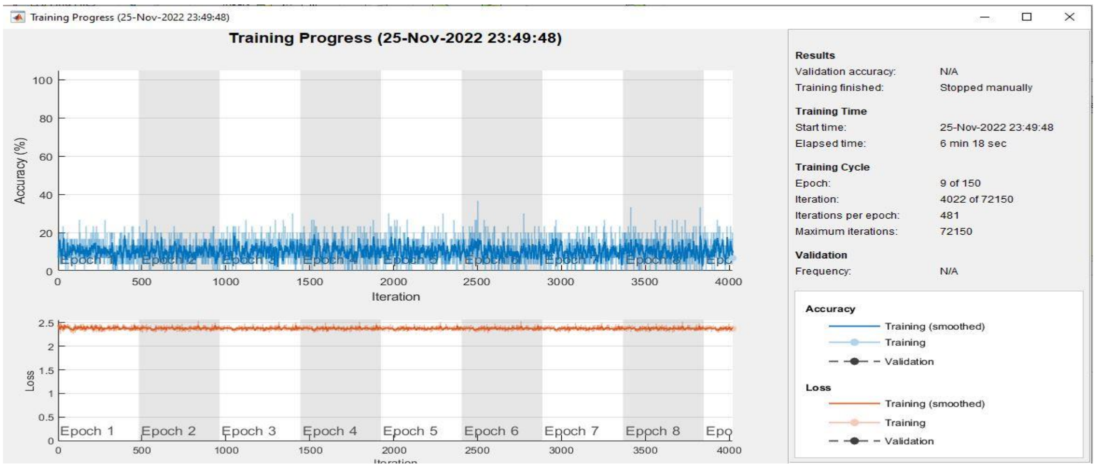

Figure 3. Training Data for Predictive Maintenance

The training progress is displayed in Fig 3. The training was done on the elapsed time of 6 minutes 18 seconds, and the training cycle was continued with the epoch of 9 out of 150. The iterations done or 4022 out of 72,150, and the iterations for epoch is 481. The maximum number of iterations done in that training cycle is 72,150.

The model develops Industry 4.0 Predictive Maintenance Architecture, algorithms of predictive maintenance modules for estimating Remaining Useful Life, and maintenance scheduling modules for supporting multiple machines/components by using the design science research approach. The industry-leading platform incorporates the architecture design and algorithms. Performance-based verification is done for the outcomes. In comparison-to-comparison approaches, the modular predictive model has a lower RMSE score of almost 19% and a higher accuracy. The production network can experience around 30% of the ideal cost and 10% of the downtime effect thanks to the predictive maintenance service enabled by designed algorithms of predictive model and maintenance service scheduling.

Table 2. Labels and Description of the Training Phase

LABELS	DESCRIPTION
Class labels	11 * 1 double
Ground truth	14442 * 1 double
Number of observations	14442
Control class	10 * 1 double
Target class	1
Validation counter	1
Sample distribution	14442 * 1 double
Error distribution	14442 * 1 double
Counting matrix	12 * 11
Error distribution by class	11* 1 double
Sample distribution by class	11* 1 double

Table 3. Parameters and Performance of Confusion Matrix during Training

Parameters	Performance during Training
Accuracy	98.5113%
Specificity	99.9422%
Sensitivity	98.5222%
Error rate	1.4887%
Correct rate	0.9851
Error Rate	0.0149
Inconclusive rate	0
Classified rate	1
Negative predictive value	0.9993
Positive predictive value	0.9868
Negative likelihood	0.0148
Positive likelihood	1.7036 e + 03
Prevalence	0.0422

Table 4. Labels and Description of Testing Phase

LABELS	DESCRIPTION
Class labels	11 * 1 double
Ground truth	6189 * 1 double
Number of observations	6189
Control class	10 * 1 double
Target class	1
Validation counter	1
Sample distribution	6189 * 1 double
Error distribution	6189* 1 double
Counting matrix	12 * 11
Error distribution by class	11 * 1 double
Sample distribution by class	11* 1 double

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Table 5. Parameters and Performance of Confusion matrix during Testing

Parameters	Performance during Testing
Accuracy	98.9336%
Specificity	99.9496%
Sensitivity	99.1597%
Error rate	1.0664%
Correct rate	0.9893
Error rate	0.0107
Inconclusive rate	Zero
Classified rate	1
Negative predictive value	0.9997
Positive predictive value	0.9874
Negative likelihood	0.0084
Positive likelihood	1.9670 e+ 03
Prevalence	0.0385

The output of the confusion matrix for optimization of the training phase using LSTM for comparison of labels and description of the matrix and number of observations in the training phase is depicted in Table 2. The parameters and performance of the confusion matrix are mentioned in Table 3. for the training phase. The training output of predictive maintenance optimization using RNN-LSTM is shown in Fig. 4.

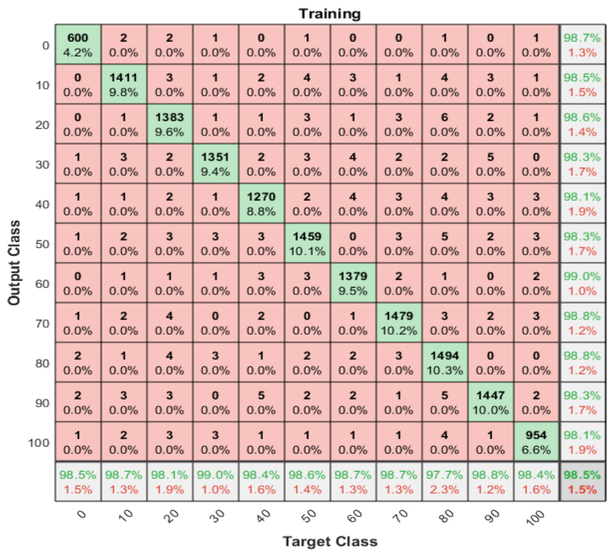

Figure 4. Training Output of Optimization of using RNN-LSTM

The output of the confusion matrix for optimization of the testing phase using LSTM for comparison of labels and description of the matrix and number of observations in the training phase is depicted in Table 4. The parameters and performance of the confusion matrix are mentioned in Table 5. for the training phase. The training output of predictive maintenance optimization using RNN-LSTM is shown in Fig. 5.

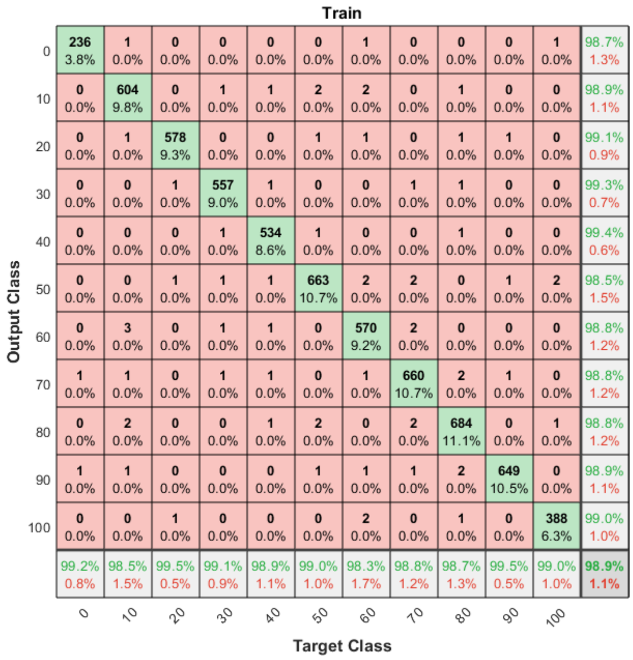

Figure 5. Testing Output of Optimization using RNN-LSTM

Validation

The evaluated parameters with test training and testing output predicted the accuracy after optimization of the predictive maintenance model. The proposed model is validated with different types of algorithms and various applications. Table 6. gives a detailed comparative analysis of our proposed model with previously given deep learning algorithms.

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Table 6. Validation of proposed predictive maintenance model

Deep learning algorithm	Accuracy	Application	Dataset
Genetic Algorithm	97%	Fault diagnosis of Bearings in induction motors[15]	Mechanical engineering construction and drive technology research datacentre
CNN MobileNetV2	98%	Covid 19 detection[16]	13808 X-ray image dataset
Bayesian optimization	92%	Electric power load through attention-based encoder and decoder[17]	American Electric Power data set
SVM. DT	96,4%	Flood Prediction[18]	Hydro geomorphological monitoring data sets
Moth flame optimization	95.38%	Segmentation of skin lesions and multi-class classification[19]	ISBI 2016, ISIC 2017, ISBI 2018, HAM 10000
Particle swarm optimization, Cuckoo search	95%	Identification of Alzheimer's disease[20]	Real-time public dataset from Chettinad health city
Spider monkey optimization	92%	Hybrid classifier model for intrusion detection[21]	Nsl kdd and kdd cup 99
Proposed methodology	98.9336%	Optimization of Predictive maintenance using jellyfish optimization and RNN-LSTM	IoT sensor data from Indian ship engine data for failure of acceleration

The validation of the proposed predictive maintenance model optimization with different types of deep learning algorithms shows that our proposed methodology gives improved accuracy of 98.9336%, which is higher than any other models.

Discussion

The input and output parameters of the training and testing model for optimization of predictive maintenance as a service model using RNN-LSTM feature selection are done through jellyfish optimization. By evaluating the performance results and confusion matrix through the training and testing output all the metrics for training and testing are classified in the confusion matrix. Our proposed predictive maintenance model with high accuracy for detection of failures in earlier stages and maintenance of Indian ships can help in avoidance of accidents in voyages and a loss of goods and money during transportation. Thus, the optimized predictive maintenance model using RNN-LSTM and jellyfish optimization proves the efficiency of improved accuracy in earlier detection of failures and maintenance in the maritime industry.

Advantages of the Study

The proposed Pd-MaaS helps in early detection of failures in the ships which is the greatest advantage in the Indian shipbuilding industry. The model is cost efficient and time saving for boosting their growth in maritime industries globally.

Limitations of the Study

For smaller shipbuilders or operators, the implementation of IoT infrastructure and predictive maintenance technologies might be expensive. IoT is useful in port and coastal areas, however real-time data transfer may experience connectivity problems when ships are at sea. There may be a lack of experts who can analyze the results of predictive maintenance and carry out the required repairs. Although it is the efficient model for failure detection during maintenance and processing with high accuracy the study includes several limitations like the type of engine ship type capacity evaluation time. With the exception of a handful, such Mazagon Dock Ltd., Cochin Shipyard Ltd., Garden Reach Ship builders & Engineers Ltd., etc., the bulk of shipyards in the nation are heavily indebted and are not turning a profit. However, the capacity of shipbuilding in India can be increased by scalability in shipbuilding, government regulation, and productivity optimization in R&D and technology.

Conclusion

To conclude the study, the proposed model can be used in the Indian Shipbuilding industry for predictive maintenance, condition and remote monitoring, cost reduction and enhanced safety. The proposed Pd-MaaS helps in the early detection of failures in the ships, which is the greatest advantage in the Indian shipbuilding industry. The model is cost-efficient and time-saving for boosting their growth in maritime industries globally. This maintenance model definitely helps India to flourish with shipbuilding industries wanting to be more productive like other countries. Training and testing our predictive maintenance model increased the accuracy by about 99.9336%, which is comparatively higher than other deep learning models used in shipbuilding industries in India.

Theoretical Implications

Data-driven decision-making is made possible by the Jellyfish Algorithm integration in IoT devices. Theoretically, predictive maintenance can be founded on current data and insights, departing from conventional time-based maintenance procedures. Theoretical implications cover investigating how IoT can improve the precision of preventative maintenance. To minimize false positives and false negatives, algorithms and predictive models must be improved.

Practical Implications

Eliminating equipment failures and possible incidents with IoT-based predictive maintenance improves ship safety, with important consequences for crew safety and environmental protection. Shipbuilders and operators now have the capabilities to effectively manage multiple vessels with the help of IoT-enabled predictive maintenance. The creation of user-friendly user interfaces and instructional materials to let ship crews and maintenance staff use and interact with IoT systems. It ensures data privacy and complies with data protection rules while protecting sensitive data from cybersecurity threats.

Future Recommendations

- In the future, the algorithm will be thoroughly investigated across all study fields. More research should be done in the disciplines of automation and mechanical engineering to improve the number of applications.
- The RCBM strategy can also be strengthened by combining the aforementioned with an IIoT-based application that automatically gathers and elaborates data, enabling in-the-moment decision-making.
- To examine how blockchain technology can be used to protect IoT data and maintenance records, ensuring data integrity, transparency, and privacy. To increase the lifespan of monitoring equipment and lower maintenance requirements, investigate the usage of energy-harvesting sensors and power-efficient IoT devices.

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Authors' Declaration

- Conflicts of Interest: None.
- We hereby confirm that all the Figures and Tables in the manuscript are ours. Furthermore, any Figures and images, that are not ours, have been included with the necessary permission for re-publication, which is attached to the manuscript.
- Ethical Clearance: The project was approved by the local ethical committee in GITAM University.

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Authors' Contribution Statement

P. S. R.was responsible for data curation, resources, visualization, and for writing—original draft and writing—review and editing. P. J. is responsible for project administration, supervision, and methodology. All authors have read and agreed to the published version of the manuscript.

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تطوير Pd-Maas القائم على IIOT باستخدام نموذج RNN-LSTM مع تحسين جيلي فيش في صناعة بناء السفن الهندية

بي إن في سرينيفاسا راو، بي في جاياسري

قسمEECE ، معهد جيتام للتكنولوجيا، جامعة جيتام، فيساخاباتنام، الهند.

الخلاصة

المشكلة: يعتبر بناء وإصلاح السفن من الصناعات دائمة الخضرة على المستوى الوطني والعالمي. تخضع السفن عمومًا للإصلاحات الدورية المقررة من قبل صناعات بناء السفن الهندية. في بعض الأحيان تفتقر الصناعات إلى الإنتاجية ويفتقر إلى التحديث ويجب اتباع بعض الأساليب الحديثة. الهدف: تركز الدراسة على تحسين الصيانة التنبؤية كخدمة على إنترنت الأشياء الصناعي من خلال خوارزميات التعلم الآلي. المساهمة الرئيسية للدراسة هي استخدام تقنيات التحسين لاختيار الميزات وRNN-LSTM لتحسين الدقة. الأساليب: تتم معالجة مجموعة البيانات المحددة مسبقًا واختيار الميزات لتحسين الدقة، ويتم تحسين اتخاذ القرار الآلي في إطار الشبكة العصبية التلافيفية جنبًا إلى جنب مع مصنف الأشجار المعزز للمجموعة الذي تم تطويره باستخدام تحسين قنديل البحر والعصبية المتكررة. نموذج الشبكة والذاكرة طويلة المدى (RNN-LSTM) للتعرف على الأنماط والمتجهات الرقمية في بيانات العالم الحقيقي بعد معالجة المخرجات ثم يتم إرسالها مرة أخرى كمدخل للشبكة المتكررة لاتخاذ القرار في السفينة عملية البناء. النتائج: من خلال تقييم نتائج الأداء ومصفوفة الارتباك من خلال مخرجات التدريب والاختبار، يتم تصنيف جميع مقاييس التدريب والاختبار في مصفوفة الارتباك. يمكن أن يساعد نموذج الصيانة التنبؤية المقترح بدقة عالية للكشف عن الأعطال في المراحل المبكرة وصيانة السفن الهندية في تجنب وقوع الحوادث في الرحلات وفقدان البضائع والأموال أثناء النقل. يوضح التحقق من صحة نموذج الصيانة التنبؤية المقترح باستخدام أنواع مختلفة من خوارزميات التعلم العميق أن منهجيتنا المقترحة تعطي دقة محسنة بنسبة 98.9336% وهي أعلى من أي نماذج أخرى. الاستنتاج: يساعد نظام Pd-MaaS المقترح في الكشف المبكر عن الأعطال في السفن والتي تعد أكبر ميزة في صناعة بناء السفن الهندية.

الكلمات المفتاحية: بناء السفن الهندية، تحسين قنديل البحر، التعلم الآلي ، الصيانة التنبؤية كخدمة، RNN-LSTM.