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ML Driven Predictive Maintenance and Life Span Detector for Bridges

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Abstract: *The safety and lifespan of bridge infrastructure are plays an important role ensuring public safety, better transportation, reducing incident Managing economic stability. This paper presents software model designed to predict the durability, remaining lifespan and maintenance when needed of bridge by using the advance technologies, including the computer vision techniques, Internet of Thing (IoT) sensors and machine learning algorithm. Our software aims to reduce the number components related of bridge failure by assessment system that utilizes historical records and real-time data.*

By using the computer vision technique and non-destructive testing to find structure problems. Also by using machine learning algorithm based on the environmental condition and daily traffic load on bridge to check the durability of bridge.

The proposed system operates efficiently and it has four phase: user interaction, historical records, and real-time data gathering predictive analysis which generates detail report of bridge condition. By finding bridge condition and durability and effective use of ML algorithms in bridge infrastructure, provide the proactive solution to bridge maintenance challenges

Keywords: Predictive Maintenance, Machine Learning, Computer Vision, Internet of Things (IoT), Non-Destructive Testing, Life Span Assessment, Real-Time Monitoring

I. INTRODUCTION

In this modern era, highways and bridge infrastructure are the crucial component of our transportation systems. Also, transportation systems play a crucial role in the economic systems and business development. With this increasing urbanization and growing need of efficient transportation system, there is the need of a reliable system to maintain this infrastructure. However, concrete bridges are subject to various forms of risks due to its degradation over time, such as cracks, dumps, corrosion, spalling etc. Generally, the cracks are earliest indicator of the structural failure.

Traditionally, the visual inspections of the bridges are taken manually by Humans. But it is difficult perform on the large bridges and the bridges located at hazardous or remote areas. Also there are several disadvantages of this inspection like it is labor intensive, time consuming and subject to human errors. Although, the accuracy of this inspection is depend upon the experience, skill and knowledge of that person.

Recent advancement in technologies like artificial intelligence, machine learning and computer vision provides the new solution for the above problem. By utilizing the above technologies our project provides the proper mechanism for the bridge maintenance. This software can able to predict the maintenance requirement, durability and the remaining life span of the bridge. By using the IoT and computer vision (image recognition) we provide some kind of automated support. Computer vision is consider to take input's like cracks, dumps, sapling on the bridge by taking the various images of the bridges. These images can be taking by the drones and cameras. Also the environmental factors like humidity or temperature causes the degradation of the bridges. By using the IoT sensors we can take the input of these factors.

II. LITERATURE SURVEY

Automated Crack Detection on Concrete Bridges

Objective of this paper is that develop an automated system using computer vision technique and machine learning for detecting crack in concrete bridge.

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Research on this paper provide how this paper primarily deal with artificial intelligences to detect the crack on concrete bridges. In this paper it uses high quality camera with the computer vision technique to capture the images of concrete bridge surface. Then this image is analysis by ML model along with various parameters to detect the cracks on surface. Because of this techniques, it reduces the need of manual inspection by human and also increase the accuracy of detection.

Advantage of this paper is reducing the need of manual inspection, which can be time-consuming and prone to human errors. Real-time monitoring and detection

However, it has several disadvantage like limitation under environmental conditions. It's detection accuracy vary depending on environmental conditions and the quality of image of captured by camera and also it only focus visual crack detection not account for structure issue of concrete bridge.

Future scope of this paper is to improve ML algorithm for detection varying environmental conditions. And integrate additional sensor for better analysis. [1]

Predictive Maintenance - Bridging Artificial Intelligence and IoT Sensors

The primarily objective on this paper is to predict maintenance of bridge by analyzing real-time sensor data using the IoT sensor and Artificial intelligences to prevent failures.

This paper highlights how the Artificial intelligences and IoT technologies are combines to enable to predictive maintenance of bridge. It explore the integration of IoT sensors to gathers real-time data and that AI algorithm to analyze that data to predict when the maintenance is needed to bridge. Predictive maintenances just like foresee equipment issue before then become critical and reduce the cost. It is preventive approach

The Advantage of this paper are it focus on preventing failure means future damages to bridge, which can save money and prevent damages. And also integrates both AI and IoT, which allow continuous monitoring multiple parameters of bridge. Because of use of predictive model enables proactive rather than reactive maintenance.

This paper cover the disadvantage of previous that it also account for structure issue of bridge.

However, it has several disadvantages like it heavily depend accurate data gather by IoT Sensor which may face challenges like sensor failure and noise. And also requirements sensor networking and data storage, making it costly to implement.

The future scope of this paper is Advance sensor technology, develop better predictive models, integrate with broader IoT systems, and conduct real-world testing. [2]

Application of Artificial Intelligence Technology in Bridge Construction and Maintenance

The primarily objective of this paper is explore AI application in bridge construction and maintenance, including smart material, predictive maintenances and UAV inspection.

This paper offer a boarder view of how the artificial intelligences is applied to entire life cycle of bridge construction and maintenances. It discusses predictive maintenance, real-time monitoring, smart material and the use of UAV's means drones for inspection of bridge from air. In this AI is applied for bridge construction in which its role to decide the construction material based on the environmental condition where we construct bridge. For inspection of bridge drones are used and it is equipment with high quality camera, IoT Sensor and AI algorithm. So data collected by drones is analgise by AI algorithm for detect any kind of damage on bridge.

The advantages of this paper is it cover the wide range of Artificial Intelligence, from construction to maintenances of bridge. It detection accuracy is going beyond the detection of visual cracks by introducing the UAVs and IoT Sensors. And also by using AI it improving safety and efficiency in bridge management.

However, It has several disadvantages is this paper cover to many things and does not focus of specific, actionable application like first paper. And the other hand because of used of advance technology my required significant investment in both AI technology and hardware, such as UAVs and IoT sensors.

The future scope of this paper is to expand use of AI application, including new technology, and improve version of AI algorithms for accurate detection. [3]

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III. EXISTING SYSTEM

IBM Maximo Application Suite

IBM Maximo is a powerful tool for managing maintenance of bridge. It used Internet of Things (IoT) by gathering real-time data and advanced analytics to help to predict the maintenance of bridge based actual condition of the assists. One of the important part of Maximo is Maximo predict, which is best for predicting when the maintenances is needed for important structures like bridges. To predict the future problem or issue it uses the past recorded data and data from IoT sensors. And then that data is analysis by machine learning, it can foresee assets will start to fail, this help prevent future risks for bridge and allowing better planning of maintenance work.

It also uses IBM Watson® Machine Learning to improve its predictions, making it easier to foresee asset failures. This help to reduce risk during operations, lower maintenance cost and longer life of bridge. [4]

Siemens Predictive Maintenance System

Siemens uses the Artificial intelligence (AI) and digital twin technology for complex system like bridge to accurate predictive maintenances of bridge. This platform collect data from IoT sensors which are place on bridge, which monitors things like temperature, humidity, and stress on the structure of bridge. By using machine learning that data is analysis then the system spot any kind of future damage on bridge means early sign of damages and suggest maintenance actions.

The new technology uses in that is digital twin of the bridge. By using this we continuously monitor or updates data from the sensors and providing a virtual view of bridge's condition. This system helps to manage a plan of maintenances before serious problem occurs. And extending the lifespan of bridge. [5]

Drones and Sensors for Bridge Monitoring

This system uses drone, also called as UAV's, to inspect the bridge from air. This is game changer in inspection of bridge from air. The drones is equip with high-quality camera and IoT sensors. The drone takes high-quality image and videos of bridge, which are then analysed by artificial intelligences algorithm to spot any potential damage, like cracks or rust. This inspection technique makes inspection easier and faster to inspect the bridge, and also in hard-to-reach places where difficult to go to human, and improves safety by reducing need for manual inspection.

By providing timely understanding bridge conditions, this system allows for proactive maintenance strategies, and reducing the risk of severe failures. The use of drones not only improve inspection accuracy but also reduces the need for costly and disturbance of manual inspections.[6]

VSL's Predictive Maintenance Initiative

VSL, in collaboration with the Chair in Construction 4.0 at Centrale Lille in France, has started a research project on improving predictive maintenance for prestressed concrete structures. This project used a large set of data and machine learning techniques to analyze historical inspection reports and data, non-destructive testing results, and other related data. By identifying the patterns of any kind of physical damage like cracks and structure issues, then the system can guide decision-making for bridge maintenance by forecasting the future condition of the bridge.

The primary objective of this system including the improving the quality of condition of assessment, increasing early warning times for significantly structure future damages and minimizing the maintenances cost while maximum traffic load on bridge.[7]

IV. PROPOSED SYSTEM

System Overview:

Bridges are the critical component they require a regular maintenance to ensure the safety. The proposed system utilizes the machine learning algorithms to predict the bridge maintenance and its remaining lifespan. The system integrates the advance technologies like machine learning, Internet of Things (IoT) Sensors and computer vision techniques

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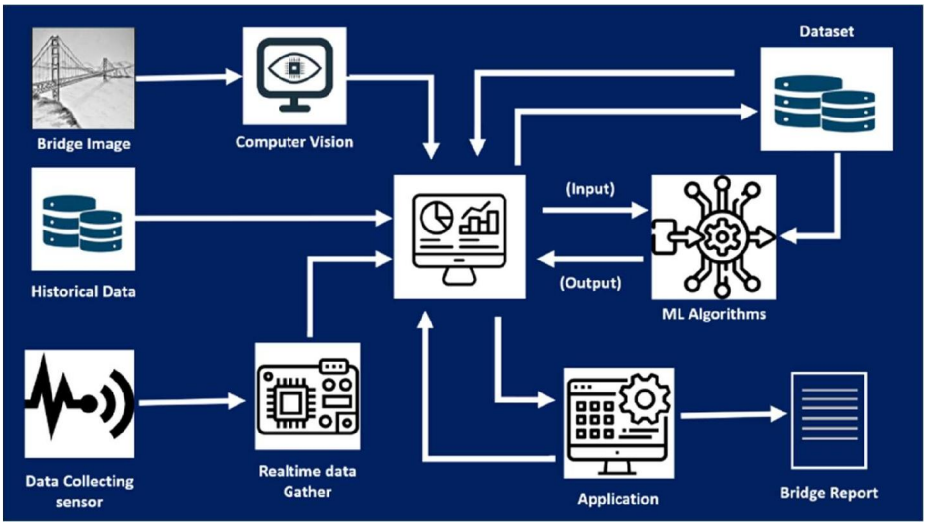
System Architecture:



The System is designed with the modular approach which includes the key components as shown above:

Data collecting sensor and Realtime data Gather: Various IoT sensors are installed at the bridges, which takes the input of the various conditions near the bridge which affect the durability of the bridge. The collected data is required to transfer to the server, for that purpose the micro controller is there which is connected to the network to transmit the data to the server for further prediction. Generally, these sensors are there to collect the various environmental conditions like the humidity, temperature, average rain fall time, if there is water bodies then what is the water level, etc.

Historical Data:

When the bridge is added to the system at that various information related its architecture, construction, location, etc is required to save at a certain location. This all data is saved in tabular format in this component. It is located at real-time database where it is easily accessible for the machine learning algorithms to predict the maintenance. Also, it makes simpler to edit, retrieve and insert the data in it. It records all the data collected by the sensors, non-destructive test results, computer vision results, maintenance history, and the overall prediction history which helps to increase the further accuracy in prediction.

Computer Vision:

The system incorporates the computer vision to automate the visual inspection which detects the cracks, voids, dumps in it. For that purpose, it requires to upload the images of the bridge taken by the drones, fixed camera's or by manually. The detected cracks, voids, and dumps are transfer to the server and the further report is created according to detected cracks, voids and dumps detected by the computer vision.

Server or central computer:

In this component all the connections and the backend processes are handled. All the other components are connected to this component. It handles the data transmission between the all components also it is responsible to record all the predictions, data collected by sensors and computer vision, and all other data regards to bridge and users.

ML algorithms:

In this component the ml algorithms are used to predict the maintenance and the life span of the bridge using the various parameters. The role of the machine learning algorithm is to outline the various areas like data preprocessing, predictive modelling, decision support system, etc. It predicts the maintenance, durability and life span of the bridges on the monthly or quarterly basic and also when the user requires.

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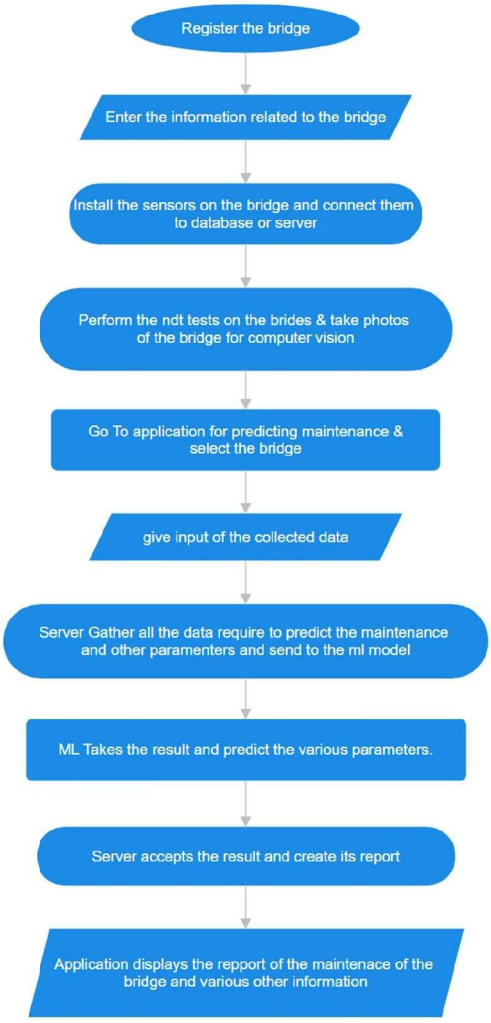
Dataset:
The dataset is crucial component of the proposed system which is require to feed or train the machine learning model. We consider the various parameters like environmental parameters, construction parameters, non- destructive test parameters, traffic parameters in it.

Application:
This component provides the interface to user and allows them to use all the functionality of our proposed system. For that we provide both the web application and mobile application. Here the user can able to track all processes related to the bridge maintenance. Also, provides functionalities like Add the bridge, predict the maintenance of bridge, view the history of maintenance, give alert about the maintenance, etc.

System workflow:



Register the bridge:
The process begins by registering the bridge in the system. In this Step we enter the information about the bridge like its name, location, constructed by, purpose, etc.

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Enter the information related bridge:
In this step the user need to enter the information related to bridge which is used to predict the maintenance, lifespan, durability of the bridge. The information be like its construction type, which material is used, its length, type, height, water cement ration, pillar thickness, when it is constructed, is there any maintenance history.

Install sensors on the bridge and connect them to database server:
The sensors which are required to take the input of the surrounding conditions are installed at the bridge in this phase. The interconnectivity of these sensors with the database is important. This is also done in this phase. These sensors provide the real-time data to the server which will increase the accuracy.

Perform the ndt tests on the bridge & take photos:
Various non-destructive tests (ndt) are perform in this phase and the images of the bridge are taken. These ndt test helps to increase the accuracy in the life span and durability prediction. Also there is the difficulty to continuous monitoring due to its high cost we take the manual photograph in this phase which will reduce the cost.

Go to application & select the bridge:
When the previous step done then in application we need to select the desired bridge which will be registered in the database. Then select the predict maintenance option.

Give input of collected data:
The input will be collected in the previous stages are feed to our application in this step. The application ask to enter the results and the user will enter these results.

Server gather all data and feed to ML:
After the users enters all the data about the bridge then the server starts gathering the data which will need as the input to machine learning modal to predict the result parameters. The data will be collected from sources like database, real-time gathered data, etc.

ML modal takes the input and predict the result: When the server feed the data to the ml modals then first by using the computer vision all the uploaded images are scanned and the result of the computer vision are feed to the further machine learning modal and by using these data ml modal predicts the result parameters.

Server accepts the result from ml modal:
When the prediction process of the ml algorithms are completed then they send the data to the server. Server accepts this data and arrange it in proper manner of the report and sends back to the application.

Application displays the report: The application accepts the report generated by the modal and displays to user in the proper format. Also, give alert about various conditions.

Key System Functionalities:
Real-Time Monitoring:
By utilising the IoT sensors it can monitor various environment, whether or surrounding conditions like temperature, humidity, flow of water, etc.

Considering the non-destructive test results:
By considering the non-destructive test results we can increase the accuracy of the ml algorithms to predict the lifespan, maintenance and impart of the surroundings on the bridge.

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Computer vision:
As there are subject to human error in visual inspection we provide the support of the computer vision to detect the cracks, voids, sapling in the bridge.

Separating the bridges in two types to increase algorithm efficiency:
We separate the bridges in two types which are steel bridge and concrete bridge to increase the algorithm efficiency.

V. FUTURE SCOPE

The proposed system are effective in predicting maintenance, durability and lifespan of bridge by using the machine learning, Internet of Thing (IoT) and computer vision technique, can be further improve in several ways. This improvement will more accurately, efficiency, and applicability. Also it ensuring that next version can face the future infrastructural challenges.
The following are key areas of development:

Integration of Advanced Machine Learning Techniques
As machine learning algorithm continues to change over time and improve, in that there are many more to use advanced models like deep learning, reinforcement learning, and ensemble methods. These advanced techniques can improve the accuracy of predictive maintenances by understanding the complex connection between environment factors (temperature humidity, etc.), traffic pattern (load distribution), and bridge health.
Deep learning for predictive analytics can analysis long-term treads and provides more accurate maintenances schedules.
Reinforcement learning algorithms allows to continuously learn from maintenances results and effective future decision dynamically.

Expansion to a Larger Dataset
The system performance could be improve by using the large and accurate dataset as much as possible, including:
• Global bridge data.
• More detailed structural data.
• Crowdsourced Data.

Real-time Autonomous Maintenance Drones
The future of bridge maintenances involve autonomous drones equipped with high-resolution camera and advance IoT Sensors and real-time monitoring. These drone would regular inspect bridges, which reduces the time and manual inspection risk.

IoT Sensor Improvements and New Sensor Types
As sensor's technology, enhanced accuracy by new type of sensor's or by improving the sensor accordingly requirements, long battery life, and by improving environmental durability.
Sensor's enhancement includes:
• Self-powering sensor.
• Multi-parameter sensing. (e.g., stress, corrosion, displacement)
• Less response time

Integration with Smart City Infrastructure
As cities grow, we have to connect the bridge maintenance system with other parts of the city's infrastructure. This helps to maintain bridge, roads, and other part of infrastructure together.
This including:
• Adaptation to Other Infrastructure
• Cross-disciplinary Collaboration

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VII. CONCLUSION

In this paper, we have discussed predictive maintenances for bridges infrastructure and its implementation by using the machine learning (ML), computer vision technique, and Internet of Thing (IoT) sensors. The proposed system is implemented to predict the remaining lifespan, durability and need of maintenances of bridges by utilizing real-time data, historical records and other techniques. By combining IoT sensors and non-destructive testing allows for continuous monitoring of environmental factors and structural integrity.

Machine learning algorithm are used for analysis data, providing proactive strategy for maintaining and increase the lifespan of bridges.

This system aims to reduce dependence and manual inspection, which are time-consuming and prone to human error.

Further research and development of this system could focuses on improving the accuracy of machine learning algorithm based on environmental conditions and integrating additional sensors for more accurate data collection. The successful implementation of this proposed system can reduce the risk of bridge failures, improve public safety and reduce the efforts of maintenances.

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