Exertion of WSN and UAV for Performance Measurements in Railway Bridges

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Abstract. The growth of information technologies had its tardiest step in the field of construction industry. With the advancements of technologies in various fields, adoption of the latest technologies is fostering the growth of construction management. The title "Construction 4.0" was framed from "Industry 4.0" a fundamental which is described as the fourth industrial reformation. The "Industry 4.0" is an innovative modification in the production sector that permits the collaboration of many advanced technologies. Specifically, it's the Engineering and Construction industry's generation of Industry 4.0, a movement towards greater digitization. It encapsulates the scientific advancement stuffs such as automation, model pre fabrication, 3D printing, unmanned flights, virtual reality, robots, and sensor nodes used to configure the construction industry with better solutions. This paper focuses only on the utilization of sensor and UAV which are used in railway bridges to monitor bridge deflections and bridge performance measurements.

Keywords: Construction 4.0, Sensor, UAV, Bridge deflections, bridge performance measurements.

1 Introduction

Bridges are passages that are constructed to commute from one place to another without disturbing the passageway beneath. They can be constructed over canals, valleys, rivers, streams and etc. Bridges are also called as flyovers or grade separators. There are many different types of bridges which serve various purposes. Designs of bridges also vary according to the function of the bridge, place where the bridge is going to be constructed, the material used and the funds available to build it.Stepping stones and fallen trees were used as bridges in the early days. Bridges are classified into many types. They are listed in the table given below.

Table1: Classification of Bridges

Sl.No	Main Classification	Sub Classification
1.	Function	Foot: Road; Railway; Road-cum-Rail; Pipe line; Water conveying(adequate); Jetty(Port)
2.	Material	Stone; Brick; stone; Timber; Steel;

I3CAC 2021, June 07-08, Chennai, India

DOI 10.4108/eai.7-6-2021.2308566

		Concrete; composite; Aluminium; Fibre
3.	Form	Slab; Beam; Arch; Truss; Suspension; Cable supported
4.	Type of Support	Simply supported; continuous; Cantilever
5.	Position of floor/deck	Deck; through; semi through
6.	Usage	Temporary; Permanent; Service(Army)
7.	With respect to water level	Causeway; Submersible; High level (normal Case)
8.	Grade separators	Road-over; Road under(sub Way) ;Fly over(Road over road)
9.	With respect to connections(Type of joining)	Pin jointed; riveted/bolted; Welded
10.	Movable bridges(over navigation channels)	Bascule,(Plate 1.14) Lifting, Swing (Plate 1.15)
11.	Temporary bridges	Pontoon, Bailey, Callender - Hamilton, Light alloy portable bridges developed by the army

However, due to predicament situations, there are lots of mishaps occurring in bridges. There are several deterioration mechanisms that can impact the integrity of the bridge structures. One of the most common damages incurred in bridges is corrosion, low cycle fatigue which is caused by plastic deformation, high cycle fatigue which is caused due to elastic deformation especially in railway bridges, small breaks in connecting elements, deformitiesin connections and permanent deformation such as bending and bucklingetc.

Deformation can also occur in the substructure elements, such as the basement, supports and pillars, and the retaining walls. The below earthelementscan infer the same deformationmechanism as explainedin the above the surface components. Concrete columns and supportscan infer deformationas a result of corrosion occurred due to recycled steel bar, freeze and thaw cycles, and silica – alkali reactions. These elementscan also experience degradation intheir performance. These problems are really a concern for the structural engineers and it is also practically not possible for humans to inspect the bridges on a periodic basis. So, incorporation of technologies such as sensors and drones for bridge monitoring will eradicate the problems incurred in the railway bridges. Railway bridges are important as it carries a huge load of passengers and goods. So, railway bridges have to be monitored in such a way that it periodically sends alert to supervisors by which effective action can be taken immediately in predicament situations.

A Sensor is a subsystem whose work is to observe the environment and notify the user if there are any unusual changes in the environment in which it is acting. Therefore, deploying sensors in railway bridges which can monitor the bridge performance factors eases the job of the concerned person. If a railway bridge is being operated in rivers, canals and seas, it is impossible for a person to inspect theunderneath condition and also the different side angles of the bridge. So, deploying a UAV which can capture all the angles of the bridges will prove to be an effective method in monitoring the railway bridgeconditions.

1.1Different Stages of Construction of Bridge

The step by step procedures that are employed in the planning of construction of bridge are:

- Survey on necessity for bridge
- Assessment of Traffic density
- Study of Location
- Study of Reconnaissance
    - Study of alternative arrangements
    - Alternative study on feasibility
- Preliminary study of Engineering
    - Plan development
    - Basic design and costing
    - Analytical evaluation of alternatives, risk analysis, and final decision
- Detailed analysis of Project Report
- Project implementation

2. Literature Survey

Themodern technologies were adopted in the civil industry among professionals of building construction, toenhance the overall fulfillment of thesector in South Africa. This approach considers that construction 4.0 will be enforced by the requirement tobuild a smart building construction area, as well as adopt tools which are required for simulation and virtual mode of operations for building constructionworks. (Temidayo et.al., 2018).

Secondly, there is focus on the functional description of the instrument and solution for the transfer of data. It mainly focuses on the data management, (Peter Furtner and DaniloDellaca , 2013) control room devices in which via a system user can monitor the information and results from any region and in any available time.

The combination of sensors and ZigBee modulesbeing deployed in bridges and it is kept as ubiquitous-node(u-node) which sends the data to the u- gateway and that sends data to the management Centre wirelesslyover CDMA technology (Chae M.J et.al., 2006).

The unmannedaerial vehicles(UAVs) which have evolved asprecious resources for placing sensing instrument where it is either more tedious to measure or poses a risk to human safety. UAVs have the capacity to promote theprocess of optical based measurement system, provide more accessibility, and decrease the overlapping of local traffic. In this paper, an autonomous vehicle is interfaced with 3D DIC which was designedfor monitoringbridges. The key features ofthe proposed model are explained in both laboratory testing andinformationgatheredfrom bridges that are currently on use. (Daniel Reagan et.al., 2016).

The railway tracks were introduced and bridge observation method with the aid of WSnetworks based on the ARM basedcontrollers. The system is modeled includingthe arrangement of sensor nodes, gatheringinformation, propagation method and signal processing techniques ofthe ad hoc wireless sensor network.

The proposed method (Vinodbolle and Santhoshkumarbanoth, 2016) overcome the human interventions which aggregate and transfer the data. The objectiveof the proposed model is to observethe arrangements to reduce the accidentsand itssafety.

The existing experimental and analytical research on vehicle-bridge interaction, performance under collision, impact and seismic loading, vibration reduction and suppression techniques and fatigue life estimation of railway bridges (Anurag Krishna et.al., 2017).

3. PROPOSED MODEL

In this proposed model, we are deploying strain gauge sensors and UAV for bridge performance measurements and bridge monitoring. Strain gauge or Strain gage sensors are those that measure strain values. It can also be defined as whose electrical resistance varies with applied force. Therefore, strain gauge sensors are attached to (say plate girder bridge model). Now,interfacing is being done between Arduino UnoR3, HX711 (load cell amplifier) and the strain gaugesensor.

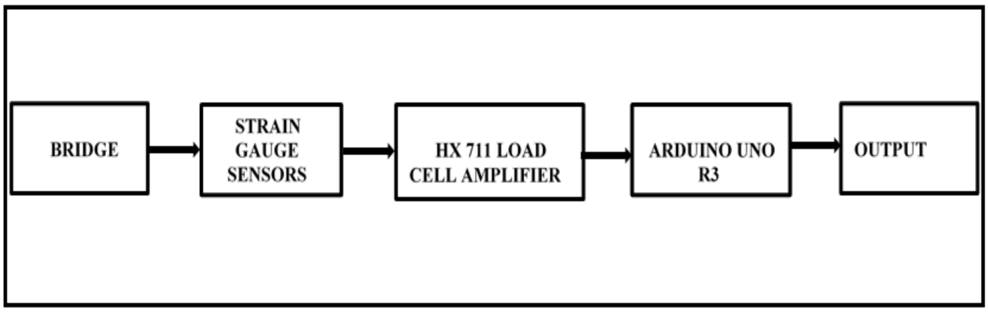

Fig1: Block diagram of proposed model

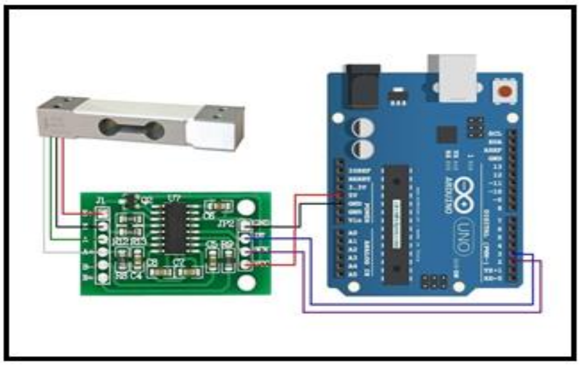

Fig2: Load cell interface with Arduino

3.1 Applications Of Sensors And Drones In Bridges

Due to the aging factor of infrastructure of the major bridges that is more than half century, the with an aging infrastructure and major bridges that are more than 50 years old, the force is applied on structural engineers to analyze our transit operation is ever increasing. Country wide lawneedseach bridge over a 20ft wide to be checked every other year. In the present scenario, monitoring of bridge does not have to dependsspecifically on regular inspections of human but can depend instead on electronic observation a bridge’s life, which could display a structural integrity issue well advance it would be noticed by a conventional bridge investigation.

The structural designers who have authority of keeping the framework sound should become known of sensor components exists that provides them in evaluating framework condition. Particularly, there are three types of sensors involved for monitoring of bridges. Strain gauge is a device that computes stress loads in bridge components that can be observed as micro movements, inclinometers computes gravity-referenced adjustments like tilt, bending, or twisting, and sensors that are positioned as linear arrangements computes macro displacements of bridge components like rocker bearings and trusses gusset plates. Buckling of the gusset plates has been described as one of the most important structural issues in older bridges.Because the sensor network required by bridge observation systems has to workfor a long period in extremely abusive situations, not all position sensors are capable for these inflexible applications.

The Alliance Sensors Group's LV-45 series is utilized in the Metro Rail safe structure and the linear position is also one of its group and inductive linear position sensors is one of them. All the sensor devices are connected to a bridges and its associated column to compute displacement of the bridge related to the pillar and rockers in all three directions over ambient temperature and time. The outputs are analysed by informationstoring method that update in regular interval an off-site observatory centre by mobile phone network based transmissions. Unmanned Aircraft Systems (UAS) or drones are employed to observe the railway for regular inspection or following an event. Small flights are a cost effective solution for closed observations that are difficult to monitor structures such as building ceilings, bridges, overhead wires and communication masts.Thedrones that aggregate information’s such as images and videos of railway framework with high – tech equipment, so the conclusion can be derived what the nature of the problem is and what kind of repairs are required.

The required code is being written in Arduino IDE platform that describes the following conditions:

i) If there exists an overload condition on the bridge, strain gauge sensor should immediately sense it and send an alert to the requiredperson.
ii) If the load is normal, it should periodically sense it and send the data to the required person. Thus, the periodic performance of the bridge can beachieved.

In real time, a series of strain gauge sensors can be deployed in railway bridges that can transmit the information wirelessly to the user. This data can be used as reference data before planning to construct another railway bridge, thereby, knowing the bridge capacity and restricting the number of bridge mishaps.

It is impossible for a person to inspect the bridge on a regular basis. Even if he/she does so, it is impossible for them to inspect every nook and corner of the bridge. Therefore, UAVs can help them ease their job. UAVs can be brought into action wherever there is a possibility of risk for humans to inspect. UAVs can be made to fly across the bridges that can totally capture the bridge structure. With the help of software such as Autodesk Inventor, the drone captured images can be designed, visualized and product ideas can be tested. Inventor allows fabricating the prototypes that exactly simulatethe stress, weight and friction, driving loads, and variety of products and their basic components in a simulated3 dimensional platform. This can also serve as an edifice in bringing future advancements in bridges.

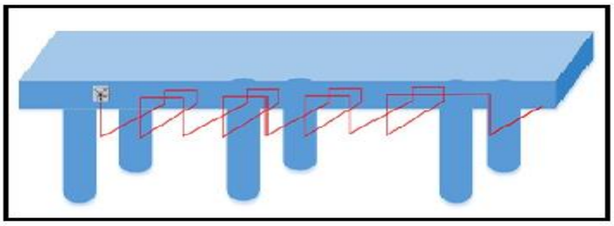

Fig 3: UAV based crack identified bridge model

The hardware unit of UAV system consists of inertial measurement Unit, Infrared sensing device, Ultrasonic and obstacle avoidance camera with a remote control and a display device. The infrared sensors and obstacle avoidance cameras and they are used to measure the vertical and parallel obstacle distances, alternatively. The remote control is employed to conduct bridges' lateral sides and underside observation, as shown in Fig.3, we use to keep the height of UAV and keeps it flying around bridges. If the UAV system is very near to obstacles, the display device will show the warning distance and give motion suggestions. There are three steps for our UAV-based crack inspection system.

- ***Flight mission and data collection:*** With the aid of obstacle avoidance unit and remote control, the UAV will fly around the underside and lateral sides of the bridge. High resolution images that are collected with the aid of HD camera at different locations. The information about the image can be stored in the storage card.
- ***UAV images processing:*** In this process a large scale map of the bridge is prepared in the form of panorama. It provides the relationship between every single image and the global map. This processing method includes distortion reduction, motion blur removal and image stitching.
- ***Crack detection:*** Cracks will be identified by a rapidly arranged learning framework that is based on random decision forests. The crack map on global basis will be produced by the superposition of crack map and the panorama.

The proposed system works according to Fig. 4. It provides a focus on developing the overall solution for UAV-based crack inspection system.

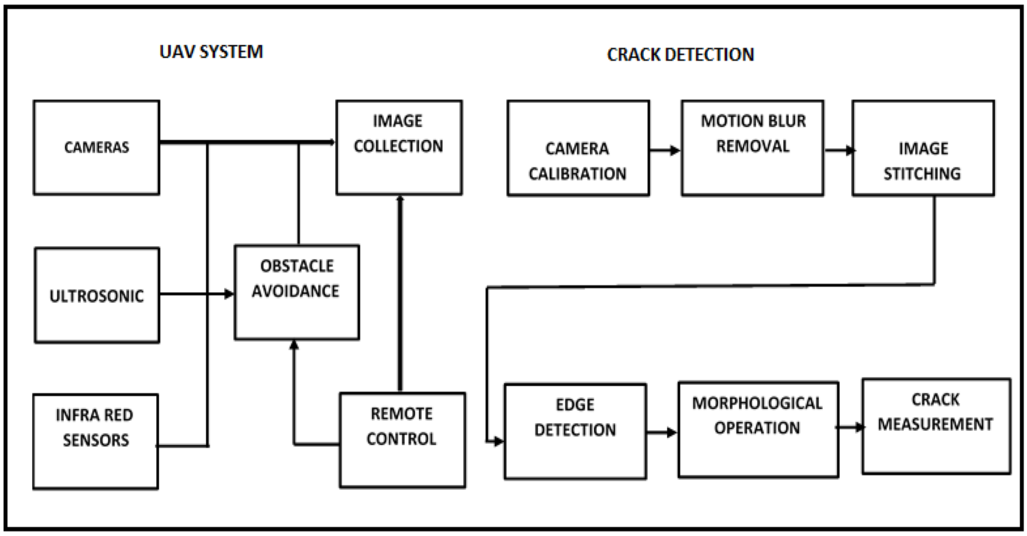

Fig.4: Solution for UAV based system

4. RESULT ANALYSIS

This model measures the deflection values with the help of strain gauge sensors which is been deployed in the bridge. The amount of deflections produced in the bridge is directly proportional to the amount of load applied to the bridge. Deflection values can be easily plotted or viewed in a graph. With the help of UAV, we can view the images of bridge structures and defects produced in the bridges via certain modeling

software which cannot be identified by human inspections. Thus, drones can replace human inspections.

Table 2: Load acting on bridge Vs Calibration

Serial Number	**Calibration Factor**	**Readings (kgs)**
1.	6500	2
2.	7000	3
3.	7500	4
4.	8000	4.896
5.	8500	5.1

According to the calibration factor we set, the load output varies. Thus, if an overload is detected in bridge, it'll be notified to the concerned person periodically.

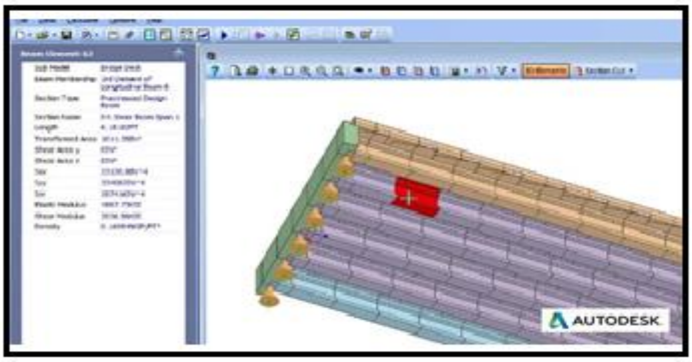

Fig.5: Crack identification graphical tracing

5. Conclusion

In this article, we have presented a novel strategy for grouping WSNs and adaptively scheduling missions for UAVs in order to collect sensor data. Compared to current approaches, the proposed ideawith the help of UAV, the images of bridge structures and defects produced in the bridges via certainModelingsoftware can be viewedwhich could not be identified by human inspections**.**The results demonstrate that UAV outperforms current methods in terms of accurate fault detection. Therefore, the adoption of technological advancements can foster the growth of civil industry and also restrict the number of accidents that occur due to bridge failures. Further research and discussion need to be carried out in bridge engineering.

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