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Advanced Railway Safety Monitoring System based on Wireless Sensor Networks

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Abstract: Railways comprise a large infrastructure and are an important mode of transportation in many countries. Railways are the lifelines of a country. The railways have become a new means of transportation owing to their capacity, speed, and reliability, being closely associated with passenger and goods transportation; they have high risk associated with them in terms of human lives and cost of assets . The poor maintenance of the railways can lead to accidents. New technologies for railways and better safety measures are introduced time to time but still accidents do occur. Thus, a proper strategy is required for maintenance and inspection of tracks.

Detection and maintenance of rail defects are major issues for the rail community all around the world. The defects mainly include weld problems, internal defects worn out rails, head checks, squats, palling and shelling, corrugations and rolling contact fatigue (RCF) initiated problems such as surface cracks. If these defects are not handled and corrected they can lead to rail breaks and accidents. There are numerous challenges to rail community and the infrastructure maintenance people such as to perform effective inspection and cost effective maintenance decisions. If these issues are taken care of properly, inspection and maintenance decisions can reduce potential risk of rail breaks and derailment.

The detection of cracks in rails is a challenging problem, and much research effort has been spent in the development of reliable, repeatable crack detection methods for use on in-service rails. While crack detection in the rail head and shear web is reliably achieved using ultrasonic and eddy current methods, neither technique is particularly effective for the detection of cracks in the rail foot. The authors present a new crack detection method for rail, which utilizes the change in infrared emission of the rail surface during the passage of a train wheel. Initial data from this infrared method are presented, from studies of both a laboratory-based three-point bend specimen and a short section of rail. The results of these two studies confirm the ability of the proposed method to locate and quantify surface-connected notches and cracks.

General Terms-Rail Crack Detector System, Railway Safety System, Wireless Sensor Network, Monitoring System etc.

Keywords-crack detection, rail track inspection, sensor node etc.

I. INTRODUCTION

A train is the popular conveyor of the people next to Bus. Railways are the lifelines of a country. The automation of train is essential as a mishap makes more damage to its travellers and the department.

Our present Model is a minor attempt to find out how the aforesaid idea can be implemented. Though this model will not serve the purpose of actual commercial use, yet it is sufficient to show the way through which we can proceed to make the Train Systems completely automatic with the aid of Electronics. The detection of cracks in rails is a challenging problem, and much research effort has been spent in the development of reliable, repeatable crack detection methods for use on in-service rails. While crack detection in the rail head and shear web is reliably achieved using ultrasonic and eddy current methods, neither technique is particularly effective for the detection of cracks in the rail foot.

In our "Indian railway system" all the control system are done through Manpower. In this present condition we must have faced the following problem.

- Wastage of time
- Wastage of energy
- Difficulty for a manual operator

Advanced Railway Safety Monitoring System

Breaks in railway lines are lines and are still one of the biggest causes of train derailment. The most common break is a crack in the crown of the rail that forms an approximate 70° angle with the horizon line. This flaw, due to its peculiar shape, is known as the kidney defect .Breaks in rail may vary from a narrow crack to the separation of a part of a rail. In some cases, the break happens inside the rail during its manufacturing process. To detect these defects, the ultrasonic method is employed: ultrasonic waves are injected into the rails by special transducers. This high-energy signal is sent in two directions at predetermined intervals. The transmitted signal is propagated in the rail and is received by receivers. The nearby transmitters send ultrasonic waves with the same frequency but with different periods. In this way, the receivers will be able to recognize the direction (left or right) from which they receive the signal. If there is a break or chafe in the rail, the amplitude of the waves received by receivers will be reduced and an alarm signal will be sounded. In Figure 1, the block diagram of the system of recognizing breaks is rails in the ultrasonic method are shown. This method is used: power is concentrated in the crown of the rail so that it becomes possible to track these defects as the ultrasonic waves are maximized . Cross defects are tracked as percentages in CSHA units. Ultrasonic sensors are alternately installed 1.75km apart from each other in the inside wall of the rail. And they must be in complete contact with the crown of the rail, in this way by increasing the number of the rail which needs to be investigated.

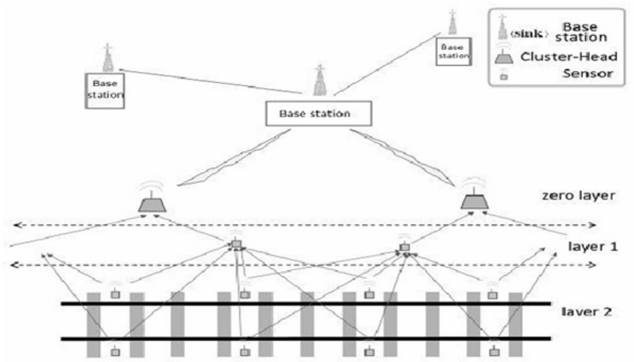

Figure 1 Block diagram of the Advanced Railway Safety Monitoring System (ARSMS.).

II. TECHNIQUES FOR INSPECTING CRACKS IN RAILWAY TRACKS

Long Range Ultrasonic Testing (LRUT)

The limitations of methods in their ability to detect defects in the rail foot, especially in the side edges away from the region directly below the web and how the LRUT method provides a significant improvement for the same.

Long Range Ultrasonic Testing (LRUT) technique is proposed as a complimentary inspection technique to examine the foot of rails, especially in track regions where corrosion and associated fatigue cracking is likely, such as at level crossings. LRUT technique is found to be suitable for examining inaccessible areas of railway tracks such as areas where corrosion occurs and susceptible areas of fatigue cracking. In different parts of the rail section (such as head, web and foot) properties of guided waves are used and are examined for their capability to detect defects in each part. A suitable array of transducers is developed that is able to generate selected guided wave modes in rails which allow a reliable long range inspection of the rail. The characteristics of ultrasonic guided waves in the rail complex geometrical profile have been identified.

GPRS module is used to get exact location of the broken rail track. PIC controller is also used owning to is low cost and less power consumption it also decreases the time used in detecting cracks.

III.BLOCK DIAGRAM

This project consists of GPS module, GSM modem, IR sensor for application of communication purpose, crack detection and MONITORING in the railway track. The GPS module and GSM modem help us to find and sending railway geometric parameter of crack detection to nearest railway station. In the present of days we are using the measurement of track distance by using high cost LVDT with less accuracy, but we use the less cost IR sensor for above process with high accuracy. The importance of this project is applicable both day and night time detection purpose. In this project IR sensors will sense the crack that signal will send to the microcontroller. Microcontroller will send signal to the GPS. Again the information that is collected by the GPS modem is passed to the microcontroller. The information provided by the GPS module of ARSMS.

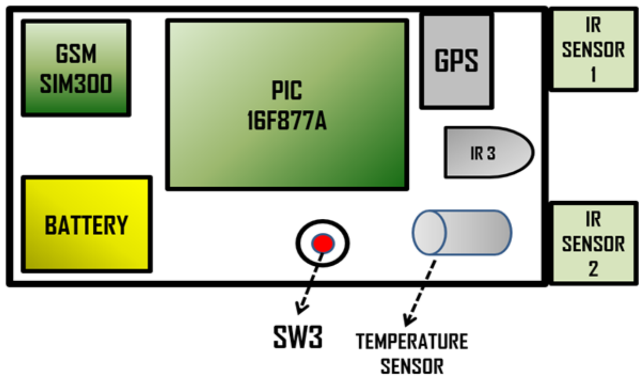

Figure 2 Functional Block diagram of Advanced Railway Safety Monitoring System (ARSMS).

The detection of Cracks is done using IR rays with the IR transmitter & receiver.IR receiver connected to the Signal Lamp or Electrified lamp with the IR sensor. CAN controller is connected to the main node and it sends the information via GSM and transmit the message to engine and to the nearest railway station. The detection of Cracks can be identified using IR rays and IR sensor.IR receiver is connected to the signal lamp and to the CAN controller. The electrified lamp is nothing but it sides of the tracks the electric lamp which is current flowing for the engines transportation. GPS system contains longitudinal and latitude positions. That longitudinal and latitude message will send to the control room with the help of GSM.

IV. RAIL TRACK INSPECTION USING SENSORS

4.1 Automatic Railroad Track Inspection

The paper [9] presents a technical survey of the automated stationary and mobile track test train systems. An automatic inspection system is proposed in the paper but it is limited to the track bed and the rails. Deployment of the rail track to cover maximum optimum segment is also discussed. Instead of six transducers employed in bi-static mode, a single mono-static mode T-R, transducers is used which offers a significant saving in material, installation, electronics, and space, as well as cost. The proposed system helps in monitoring high risks in track beds by deploying sensors at particular areas and by the use of probabilistic selection method to identify high risk areas.

4.2 Wireless Sensor Networks Based on Sensor Nodes

The concept of fuzzy logic is used by author's deployed sensors. A model for placing sensors on the railway track is described in the system [10]. There are many base stations or control centres which collect the data from the numerous sensor nodes distributed on the railway tracks. Multi-layer routing is used to transmit the sensed data to control station. The sensor nodes transmit the data to their nearby cluster heads. Multi-layer routing is used; the nodes in lower layer transmit their data to higher layer instead of transmitting it directly to base station.

For detecting cracks on rail tracks ultrasonic method is used. Ultrasonic waves are injected into the rails by special transducers. High-energy signal is sent in two directions at predetermined intervals. The transmitted signal is propagated in the rail and is received by receivers. The nearby transmitters send ultrasonic waves with the same frequency but with different period's .In this way, the receivers will be able to recognize the direction (left or right) from which they receive the signal. If there is a break or chafe in the rail, the amplitude of the waves received by receivers will be reduced and an alarm signal will be sounded. To track cross (horizontal) defects that happen in the crown of the rail, the ultrasonic method is used: power is concentrated in the crown of the rail so that it becomes possible to track these defects as the ultrasonic waves are maximized. Ultrasonic sensors are alternately installed 1.75km apart from each other in the inside wall of the rail and they must be in complete contact with the crown of the rail, in this way by increasing the number of the rail which needs to be investigated.

Collision in the tracks can be avoided using sensors and a technique based on IR Rays & Sensors [11]. Collisions are avoided by fixing the sensors in the train wheels and transmitting the rays in the track. The trains coming from opposite direction also have the same option. If two trains are on same track, the rays will get collided and get reflected back to the respective engines and the LED or Alarm will blink that will help in stopping the train.

A failure tolerant (FT) algorithm is proposed [12] for monitoring the rail lines. The algorithm is based on the simultaneous use of movable and fixed sensor network design and has the ability to send information as online-offline. The proposed algorithm reduces fault tolerance and energy consumption in the network thereby increasing network lifetime. The algorithm has two parts fixed and movable. The fixed algorithm works for sensor networks that are in places such as bridges, tunnels and special points. This algorithm collects information about seismic data and the bridge balance and Cracking in the foundations of bridges and Pressure on the bridge and investigates this information. Movable algorithm, displays how to collect information of fixed sensor network by installed networks on the locomotive or monitoring cars , it also check the balance point line and register in a data position. In this system, GPS will detect coordinates of points that their data is registered.

4.3 Track Surveying with Sensors

For Track surveying with sensors the authors have proposed an architecture which has sensor nodes deployed along a railway track as shown in Fig 3. The network consists of numerous control centres (sink node) that are connected through a wire lined connection, and the sensor nodes are deployed along the railway lines. The sensor nodes collect the necessary data and forward the data back to the sink.

An innovative railway track surveying procedure is described that uses sensors and simple components like a GPS module, GSM Modem and MEMS based track detector assembly [4]. The surveying system proposed in this paper can be used for both ballast and slab tracks. The railway geometrical parameters which are Track axis coordinates are obtained with integrated Global Positioning System (GPS) and Global System for Mobile communication (GSM) receivers.

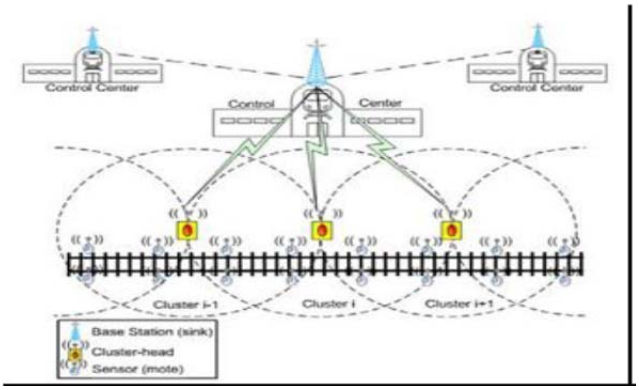

Figure 3. Architecture of Track Surveying with Sensors

The authors have proposed a cheap, and simple scheme with sufficient ruggedness which is suitable in the Indian scenario that uses an LVDT arrangement to survey track geometry by using multi sensor, which has proved to be cost effective as compared to the existing methods. This sensor very accurate detection and it will send information immediately by using GSM. The system can be operated in tunnels without interruption

Bridge damage status is monitored by the sensor and wireless modules, when the sensor not getting signal, immediately nearby wireless system notifies and alert or informs to the current train on the track. The above task can achieve through microcontrollers, GSM, LVDT.

V. Rail Defect Detection Procedure

Rail defect detection is a process for which many different detection techniques have been studied and implemented. In general, for a defect detection system, the following need to be made available: a system of sensors which traverses the rail tracks, a data acquisition system, an algorithm to process the data and classify the signals as those arising from a break or no break and finally a means for notifying the GPS position of the break to authorities so that necessary action may be taken. Figure discusses the flow of the process of fault detection and remediation in case of rail break instances. A schema of the discussed method is given in figure 4

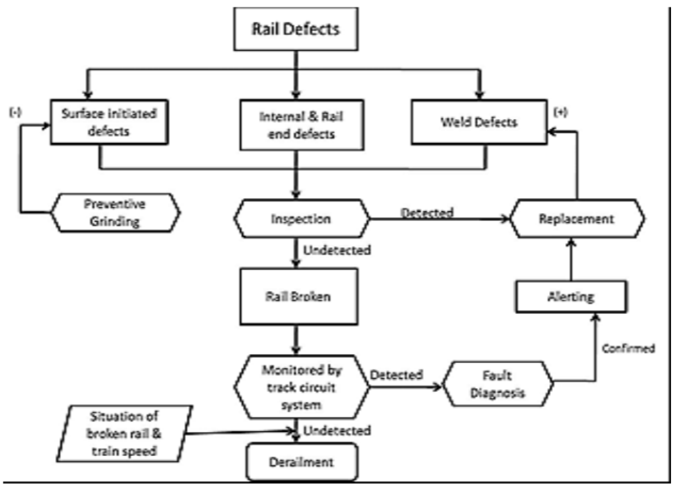

Figure 4 Break Detection procedure

VI. MONITORING SYSTEM

The data from sensors is treated as either a time series, where data are produced continuously or periodically, or a sequence of readings where data is generated *ad hoc*, for example, generated every time a train passes. The data can be monitored by searching for thresholds (triggers), known problem signatures (classification), identifying unknown events (short-term analysis using outlier detection), or identifying drift over a longer period of time (long-term outlier detection).

Condition monitoring can be performed continuously or periodically. Continuous monitoring should detect a problem straight away but it is often expensive; energy hungry, which is a problem for WSNs where the network components need power; and the sensor data are very noisy, which requires careful pre processing to ensure accurate diagnostics. Periodic monitoring is cheaper, uses less energy, and allows time for data cleaning and filtering but a problem will only be diagnosed at the next processing run. This may be acceptable for some situations that change slowly such as cracks developing in bridges but for time critical scenarios, then continuous monitoring is necessary.

In basic condition monitoring, the system is only able to distinguish between normal and abnormal conditions (no fault or fault). Beyond this, systems exhibit increasing levels of monitoring sophistication as outlined by the staircase of structural health monitoring of system will comprise complex hardware, custom algorithms, and software to allow the diagnosis and/or the prognosis and even the solutions.

The topology of WSNs often varies over time. One very important factor in this topological variation is the mobility of the sensor nodes. Its subdivided the communications network for their WSN into two: the fixed network relates to sensor nodes in fixed locations such as bridges, tunnels, and special points, whereas the movable network relates to sensor nodes attached to locomotives or rail wagons. The data for the movable network are logged with accompanying GPS coordinates. Movable (on-board) sensors can monitor the whole track length travelled by the train but only monitor the sections of the train where the sensor nodes are attached. In contrast, track-mounted (fixed) sensor nodes can measure the whole train as it passes but only at specific points where the nodes are mounted on the track. This trade off needs to be considered when designing the node placements.

WSN monitoring provides continuous and near real-time data acquisition and autonomous data acquisition (no supervision is required); increased frequency of monitoring compared with manual inspection; improved data accessibility, data management, and data use compared with non-networked systems as all data can be collected and processed centrally; the ability to combine data from a wide variety of sensors; intelligent analysis of data to “predict and prevent” events using intelligent algorithms; the ability to turn data into information about the status of important structures, infrastructure and machinery; and, a global data view that allows trending information to be determined where degradation is happening slowly over a relatively long period of time.

WSN monitoring can be used to:
1) maintain process tolerances;
2) verify and protect machine, systems and process stability;
3) detect maintenance requirements;
4) minimize downtime;
5) prevent failures and save businesses money and time;
6) request maintenance based on the prediction of failure rather than maintenance running to a standard schedule or being requested following an actual failure.

Track monitoring systems also play a vital role in maintaining the safety of the railways. Monitoring bridges and tunnels (discussed in the previous paragraphs) uses sensors to identify and analyze defects (cracking and displacement) in large structures. In contrast, track monitoring involves identifying and analyzing defects in long narrow metal rails. Tracks can crack and displace like bridges but also twist and tilt (incline). Hence, track monitoring can vary from detecting settlement and twist such as that caused by nearby tunnelling or excavation [2]; to measuring the forces exerted by train wheels on the tracks; to monitoring the development of cracks and structural flaws as trains pass and over the longer term.

Monitoring the impact of passing trains is important for two reasons: it can detect track damage, but it can also detect damaged trains. An detailed state-of-the-art automated systems using track-mounted sensors for wheel condition monitoring. Excessive forces, particularly where the train has a defect such as out-of-round wheels, flat wheels, or unbalanced axle loading, can crack sleepers, damage the rail head, and cause failure of rail by either growth of fractures, or fatigue and fracture of in-track welds [10] used FBG sensors for train identification, axle counting, speed and acceleration detection, wheel imperfection monitoring, and dynamic load calculation by placing them in different positions on the track. Monitoring the forces exerted using strain sensors can identify defective axles and wheels or incorrectly loaded trains. Analyzing the track vibration data produced by accelerometers and the AE signal transferred through the rail from AE sensors can also detect out of round wheels as trains pass in corporate an inductive axle-counter block into their system for assessing the train speed. The speed affects the expected vibrations; thus, the speed can be built into the wheel analysis model. Detecting wheel faults can also pinpoint trains that are at risk of causing a derailment. In the risk of derailment is represented by the ratio between the lateral and the vertical force (L/V ratio), which quantifies the relationship between the applied load and the deflection of the track [10].

Condition monitoring protects both the trains and the track, increases the track and train reliability and allows repair to be scheduled. If the track has been marked as defective and awaiting repair but is still usable, AE sensors can be attached to monitor the defects and ensure that they are not getting worse. Track awaiting repair usually has a speed restriction enforced so, if it is monitored, this may not be required.

WSNs enable continuous real-time capture of data. However, WSNs need to be able to handle the harshness of outdoor long-term condition monitoring; often in hostile environments and must minimize energy us age as the nodes are not attached to a wired power supply. They typically use low-power sensors powered by batteries although authors are investigating alternative power supplies such as local energy generation. Hence, the network to enable data capture has to be carefully designed to overcome these factors and prevent transmission errors, latency, network outages, missing data, or corrupted data.

VII. RESULTS

The model of our ARSMS (Advanced Railway Safety Monitoring System) is developed partially to some content. Considering the cost and time constraints the train engine and control room (nearest railway station) have been developed and also we have just created a database using visual basic in pc and we are in process of linking together the train engine and the server. But for the prototype model we have linked train engine, rail track and control room using GPS & GSM.

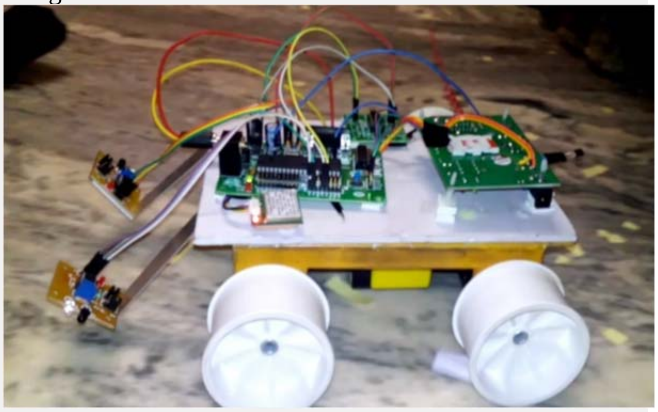

Figure 5 GPS & GSM based Advanced Railway Safety Monitoring System

In this project IR sensors will sense the crack that signal will send to the microcontroller. Microcontroller will send signal to the GPS. Again the information that is collected by the GPS modem is passed to the microcontroller. The information provided by the GPS system contains longitudinal and latitude positions. That longitudinal and latitude message will send to the control room with the help of GSM.

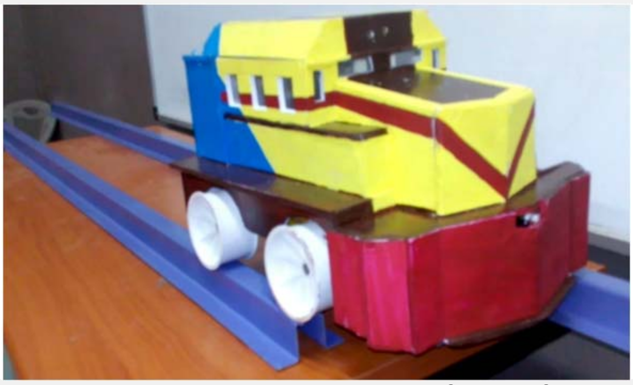

Figure 6 Rail track having crack in identification of Train engine.

IR sensors are two main parts are there in that one is transmitter and another one is receiver. In our project mainly IR sensor is used for the purpose of crack detection which means the IR sensor always emits the signal when the signal is getting stopped it will send high pulse to the microcontroller, and the other one is an object detector. If any object is on track it will sense and it will send signal to the microcontroller.

When a detecting of cracks found in the railway tracks using IR sensor, if any of them is found the cracks are sensed by the IR sensors and alert message is send to the control room using GSM, and the alert message includes the Latitude & Longitude of the location where the crack is found by using GPS.

Figure 7 Object being monitoring by using sensor in train engine

Along with this an object detector continuously monitors the tracks for any obstacles and sends the message to the control room temperature sensor is kept at the front for checking out any fire related issues.

This project to provide an efficient system for detecting the cracks, objects and fire found in the railway tracks. And also to create a MAN_FREE surveillance in the railway system. This is for a more reliable system in monitoring the tracks.

VIII. CONCLUSION

This ARSMS paper has reviewed the range of WSNs used for condition monitoring in the railway industry. The emphasis is on the practical engineering solutions, principally which sensors devices are used and what they are used for; and, identification of sensor node configurations and network topologies.

Accidents occurring in railway transportation systems cost a large number of lives. Many people die and several others get physical and mentally injured. Accidents are the major causes for traumatic injuries. There is certain need of advanced and robust techniques that can not only prevent these accidents but also eradicate all possibilities of their occurrence. Wireless sensor network which continuously monitors the railway track through the sensors and detect any abnormality in the track. The sensor nodes are equipped with sensors that can sense the vibration in the railway track due a coming train. The geographical positioning sensors are placed on the trains. These sensors send the train's geographic location. The complete process is needed to be real time in nature and should meet the deadlines. Optimization of the communication protocol and real time working network with minimum delay in multi-hop routing from the nodes to the train using a static base station is needed, so that the decision making can be done and the decision is forwarded to the train without any delay.

This paper focuses on the sensor technology used to generate condition monitoring data to enable practical condition monitoring systems. These data must be managed and turned into useful information to generate useful information. Condition monitoring systems must store large quantities of data to build models for analysis. The data must be validated first to ensure that they are correct and error-free (sensor faults, noise, null values, communication errors, etc.). This process may even be performed in the sensor node's microcontroller; thus, only valid data are transmitted thus minimizing the transmission load. These data can then be processed in a number of different ways to generate information. Once data are collated, they can be analyzed using robust algorithms to identify faults in near real-time. Algorithms need to be robust as WSN data is noisy, can be intermittent, may contain errors, has many interdependencies and the data volume is very high. The WSN data can also be stored and analyzed over longer time periods to identify long-term progressive faults such as a slowly developing crack.

IX. FUTURE WORK

In the future, ever more data will be collected from railway infrastructure and vehicles. This inevitably leads to a requirement for the railway industry to develop standards for data collection [126] and processing encapsulate railway data and ensure consistency for transmission and processing. Different systems and different companies can then share data using a consistent interface.

As more and varied condition monitoring systems are developed, then there is a further requirement of standardization of presentation of decisions and information across these systems for consistency and to allow integration of multiple systems. Equally, many condition monitoring algorithms are "black boxes" providing little or no explanation of decisions. In the staircase of structural health monitoring of geographical location using multiple compute nodes or even machine with multiple processing cores or at the same distributed processing, where the data are processed at multiple geographical locations, and the results are assimilated at a central location, nodes to speed execution.

In the future, condition monitoring will be able to exploit cheaper, more robust and more pervasive hardware. New data processing techniques will generate more accurate, robust, and reliable models from existing and new sensor data. Data and processing will be standardized. The number of sensors will increase in the future, and the number and distribution of monitored objects will expand then the system can estimate. Systems will be secure and provide clear and detailed decisions and recommendations.

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