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Structural Health Monitoring: Novel Approaches

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STRUCTURAL HEALTH MONITORING: NOVEL APPROACHES

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ABSTRACT

In this research paper, X-ray Spectroscopy based approach to monitor the health of various structures (like buildings, railway bridges etc) is proposed. Also, other imaging techniques are proposed for Structural Health Monitoring (SHM). Novel approach to vibration analysis of sensor outputs is proposed. Finally, the vision of Mission Control Center (MCC) for networking various structures, monitoring the health of them and take necessary control action (using the associated Cyber Physical Systems) is proposed.

1. Introduction:

Structural Health Monitoring (SHM) of aeronautical, mechanical, civil, electrical and other systems has received wide attention from the research community. Specifically, vibration, wave propagation and multi-physics methods were specifically progressed alongwith other approaches. In mechanical, civil engineering disciplines, non-destructive testing has been investigated for structural health monitoring. The author became interested in the research area of SHM and attempted novel approaches to achieve this goal. This research paper provides initial efforts of the author on this important research discipline

This research paper is organized as follows. In section, structural health monitoring based on imaging techniques is discussed. In Section 3, a novel approach to structural health monitoring based on vibration analysis is proposed. In Section 4, Mission Control Center (MCC) for structural health monitoring is proposed. The research paper concludes in Section 5.

2. Structural Health Monitoring: Imaging Techniques: X-ray Spectroscopy:

For imaging the health related conditions of humans/lower level animals (such as broken bones, teeth etc), X-radiation based imaging is routinely utilized by doctors. The author was motivated by the curious idea that structural faults in concrete brick-made, mud brick-made, wooden-made buildings may be detected by X-ray based imaging. The following Figure 1 illustrates the conceptual details related to such an imaging approach.

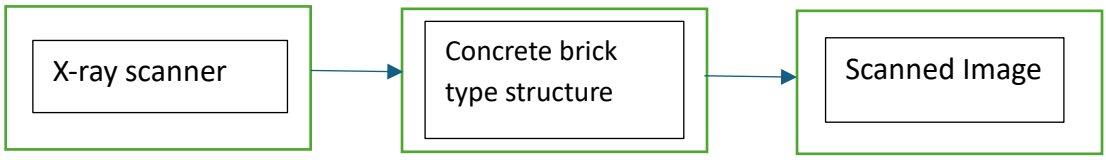

Figure 1. Block Diagram of X-Ray Imaging of Structures (Civil, Mechanical etc)

Based on experiments conducted on SMITH'S DETECTION X-RAY SCANNER, the following observations were made. The colour of output image from scanner for various material based objects is summarized in the following table

Serial Number	Material	Colour
1	Metal	Blue
2	Plastic	Blue
3	Water	Orange
4	Aluminium	Blue
5	Wood	Brown
6	Porcelain	Green
7	Card Board	Blue
8	Mud brick	Green

We are currently experimenting with various other materials and expect to determine the colour output on the X-ray scanner monitor. In effect, we are exploring the research area of 'X-RAY SPECTROSCOPY'.

It is well known that medical doctors routinely employ Computer Aided Tomography (CAT) scans, Magnetic Resonance Imaging (MRI) scans, Positron Emission Tomography (PET) scans, FMRI scans to investigate the condition and issues related to organs such as brain, heart etc. It is very natural that such sophisticated imaging techniques can also be employed with non-destructive imaging of objects made out of materials like concrete, wood, porcelain etc.

- **Image Processing & Analysis of Scanned Images:**

  The scanned images from X-ray scanner and other imagining equipment are processed by various image processing techniques. For instance, various types of noise corrupting the images are first removed, using say median filter. The cleaned-up images are subjected to image analysis for determining, say the type of object of interest (being scanned). Such approaches can be automated using, say deep-learning (convolutional neural networks) based classification schemes. They are of commercial interest for deployment in Airports, Hotels and other organizations.

3. **Structural Health Monitoring: Vibration Analysis**:

   Vibration analysis of cantilever beams and other structures is routinely carried out to monitor the health condition of various structures (bridges, building etc). The vibration signal is processed in various ways to infer the health condition of structures. Some of the approaches are

   (i) Frequency Domain Approach: The signal is transformed into frequency domain using Discrete Fourier Transform (DFT). The Fast Fourier Transform (FFT of received vibration signal is processed to extract the deviation of vibration from that of healthy structure

   (ii) The vibration signal observations are directly processed using the machine learning techniques such as Support Vector Machines (SVMs) for detecting anomalies in the received signal.

After careful examination of such approaches, the author proposed the following hybrid approach:

The vibration signal is transformed into the frequency domain using DFT. The transformed signal observations (i.e.FFT output) are processed using machine learning techniques such as SVMs to infer important information related to the health of structure under examination. We are also proposing Convolutional Neural Network (CNN) based approaches for FINE GRAINED classification of health condition of the structure.

4. **Structure Health Monitoring (SHM): Mission Control Center (MCC):**

   In the above sections, we discussed structural health monitoring of individual structures (buildings, railway bridges, dams etc). The technologies like Wireless Sensor Networks (WSNs), Internet of Things (IoT) promise the potential to communicate the health condition of networked structures wirelessly to remote Mission Control Center (MCC). The information received at MCC is processed using SHM based approaches. It is possible to LOCALIZE (spatially and temporally) the FAULTY/COMPROMISED structure and take corrective action using associated Cyber Physical System (CPS).

5. **Conclusion:**

   In this research paper, X-ray spectroscopy based approach for structural health monitoring is innovated. Also, a novel approach to vibration analysis based on machine learning techniques in frequency domain is proposed. Finally, the vision of Mission Control Center (MCC) for remote monitoring of the health of structures remotely and take necessary corrective action using the associated cyber physical system is innovated

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