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Structural Health Monitoring: Novel Approaches

Rama Murthy Garimella

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STRUCTURAL HEALTH MONITORING: NOVEL APPROACHES

Garimella Rama Murthy,

Professor, Mahindra University,

Hyderabad, Telangana, INDIA

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.

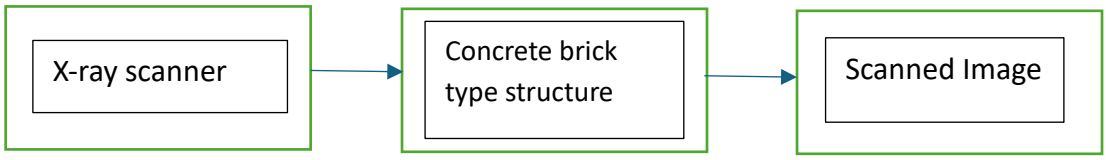

Figure 1. Block Diagram of X-Ray Imaging of Structures (Civil, Mechanical etc)

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	Metals: Al,Cu, Steel	Blue
2	Plastic	Orange
3	Water	Orange
4	Copper + Water	Blue Contour & Green
5	Wood	Brown/Orange
6	Porcelain	Green
7	Card Board	Blue
8	Mud brick	Green
9	Aluminium + Water	Blue & Orange
10	Steel + Water	Blue & Green
11	Aluminium + Salt + Water	Blue & Orange
12	Solidified Salt	Green

13	Steel + Water + Salt	Blue contour+ Green
14	Copper+ Water + Salt	Blue Contour + 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'. More generally, we propose RADIATION SPECTROSCOPY (based on Gamma Radiation, Microwave Radiation etc)

- **Non-Destructive Imaging of Materials:**

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.

- **Radiation Spectroscopy**:

  In this research paper, the author proposed the utilization of X-ray radiation for bombarding various phases and forms of matter. The "spectral signature" of the materials provides interesting clues into the composition of matter. In fact, the hypothesis proposed in [3] could be validated based on X-ray spectroscopy. Other forms of radiation, such as cosmic radiation could provide us interesting clues

about the origin of universe and fundamental units of matter/energy systems.

- **Bombardment of Materials with mass/energy strings: Spectroscopy**: In view of the above experimental investigation and the Rutherford gold foil experiment (i.e. bombarding gold foil with alpha particles), it is natural to attempt the following investigations:
  A. Bombarding various types of materials (in the form of solids (e.g. foils, sheets), liquids, gases) with alpha, beta, gamma radiation (resulting from nuclear decay) and observing the resulting radiation if any
  B. Bombarding various phases of matter (solids, liquids, gases) with stream of fundamanetal particles such as neutrons (as in nuclear fission with uranium), positrons etc and observing resulting mass-energy reactions
- **Implications of the Experiments to Condensed Matter Physic**s: **String CondensationL Formation of Elements in the Periodic Table:**

  In view of the ideas reported in [3], all forms of matter is arrived at by condensation of photons. For instance green photon condensed into electron in our neighbourhood on the universe. Infact, "strong condensation" accounts for STRONG FORCE and "weak condensation" accounts for WEAK FORCE (responsible for nuclear BETA-DECAY i.e. nuclear fission on bombardment of Uranius-238 with Neutrons).
  As a natural continuation of the ideas, the author asked the following question:
  Q: Why does the water in Oceans contain Salt and other compounds ?
  Since salt is Sodium-Chloride, the author examined the periodic table of elements (in our part of the universe) and realized that the elements Hydrogen, Sodium are both in the same group i.e. GROUP 1 i.e. the number of valance electrons is 1 (i.e. atomic number is 1). It is expected that condensation of hydrogen and oxygen (both gases) resulted in water and the condensation of sodium, chlorine elements led

to salt in the oceans. Detailed explanation of "condensation of radiation into various materials" can be endowded with mathematical explanation using 'CHEMICAL GROUPS". The logical approach to CONDENSED MATTER PHYSICS takes into account the existing WELL KNOWN FACTS IN PHYSICS AND CHEMISTRY (physical and chemical laws). Our approach provides a comprehensive MATHEMATICAL, PHYSICAL AND CHEMICAL EXPLANATION OF VARIOUS FORMS OF MATTER WITH "CONDENSATION OF STRINGS" STARTING WITH THE PHOTONIC STRINGS.

- **Physics based Explanation of the X-ray Spectroscopy Experiments**: When X-radiation is passed through liquids such as water (without salt i.e. sodium chloride is not dissolved in the water), the resulting output from the X-ray scanner exhibits orange colour i.e. we expect the "orange phtons [3] to be released. The hydrogen and oxygen molecules exhibit "orange" photon based sprectral signature when bombarded with x-radiation. WE EXPECT THAT OTHER FORMS OF RADIATION COULD POTENTIALLY PROVIDE DETAILED CLUES RELATED TO THE CONDENSATION PROCESS AND COMPOSITION OF MATTER.

  The author is currently actively providing a COMPREHENSIVE EXPLANATION OF THE CONDENSATION PROCESS IN VIEW OF THE PERIODIC TABLE OF ELEMENTS. More interestingly PERIODIC TABLE FOR "NANO-MATERIALS" is being actively pursued. THE AUTHOR ATTEMPTS TO UNIFY "STRING THEORY", NANO-SCIENCE, CONDENSED MATTER PHYSICS and other natural laws governing matter, radiation at the COSMIC SCALE AS WELL AS ATOMIC SCALE.

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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