Vibration Signal Analysis in Cantilever Beam using Machine Learning

A Minor Project

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by

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Abstract

Vibrations are common phenomena seen in mechanical structures that can be detrimental to many systems. If not monitored, they can cause damage to structures, Vibrometer is sensor used for measuring vibrations of mechanical structures, machines, as well as sound level in an area and will collect lot of data that is to be analyzed to determine the strength of the structures. Machine learning is the basic working technology for prediction and determining the work proposes system aims to predict the health of a structure, converting the cantilever beam vibration reading to graph which is able to give the correct state or health of the structure. This work will cover all the major challenges faced due to natural down fall of quality of structure .The aims to able to check the Structural Health and able predict the condition of the structure .

The goal here is to make the system real time by converting the reading of the vibrometer into visual wave to able to predict the value or to keep a check . Once the model is build on the dataset then the aim is to use the real or random values and check that the outcome is accurately fits or is able to provide the solution. This work proposes a real time implementation of Structure strength prediction using machine learning techniques.

Contents

List of Abbreviations

SHM – Structural Health Monitoring

Hz – Hertz

RPM – Revolution Per Minute

FFT – Fast Fourier Transform

PZT – Lead Zirconate Titanate

LDV – Laser Doppler Vibrometer

M Hz – Mega Hertz

FM – Frequency Modulated

DFT – Discrete Fourier Transform

EMA - experimental modal analysis

MATLAB – Matrix Laboratory

FEM - finite element modelling

DTFT - discrete-time Fourier transform

LIDAR- (light detection and ranging)

ToF – Time of Flight

CNN – Convolutional Neural Network

AI – Artificial Intelligence

ML – Machine Learning

DL – Deep Learning

SVM – Support Vector Machine

PSVM – Proximal Support Vector Machine

GUW – Guided Ultrasonic Wave

FML – Fibre Metal Laminates

MEMS – Micro Electro Mechanical System

CV – Cross Validation

ANN – Artificial Neural Network

CSV – Comma Separated Value

CPU – Central Processing Unit

GPU – Graphics Processing Unit

RAM – Random Access Memory

USB – Universal Serial Bus

AFDD - Automated Frequency Domain Decomposition

FEMU - Finite Element Model Updating

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Chapter 01
Introduction and Objectives

One of the most common phenomenon that occurs in every structures and machine is vibration .

Vibration in the machine and structures is one of the most important concern to be monitored . Vibration if not monitored can cause huge damage and malfunctioning of structure and machine . Preventing machine from being damaged, some main parameters are needed to be taken care that are temperature , noise , sound and most important vibration.

To measure the vibrations in the machine and structure various electronic component such as resistors , capacitors , piezoelectric material etc , are used in construction of a machine called Vibrometer. Measurement of vibration in any machine and structure is very important to detect the life of the machine and structure so as to prevent it from destruction .[1]

Structural Health Monitoring(SHM) has become an one of the most important topic since last few years in many fields. Guessing the health condition and understanding the unique characteristic of any structure through assessing measure physical parameters in real time is the main goal of SHM. The basic aim of using SHM is to guess and identify the damage or changes from the vibration signal of the dynamic system to detect, locate, and quantify any damages in the existing system structure or machine.[2] .

1.1 Vibration Transducer

Vibration transducer is the device that converts the vibration input of the machine or structure into the electrical signal in different forms that provides the requires necessary informations .
It takes input of energy in one form and convert it into some another form with some known correlation between input and output energy. There are various types of vibration Transducers some of the most known vibration transducers are , Fast Fourier Transform (FFT) analyzer , Lead Zirconate Titanate (PZT) actuators , Accelerometer etc . [1]

Vibration transducers can be connected to an easy-to-read display which allows the user to control the current vibration level, to check the production process. Vibration transducers combined with a control system can automate completely a machine, accelerating production and preventing damages caused by strong vibrations and their expensive repair costs. Vibration Transducer guides structures and machines and help them to protect against damage and malfunctioning. vibration transducers help the user to control maintenance intervals to solve the problem before the machine or structure is destructed. [3]

Vibration derives from many various sources that includes fluid flow , magnetic field , translating and rotating elements , imbalances , interaction and frictional contact within the structure or machine. The mode of vibration depends upon the structural properties , geometry and boundary condition of a structure that may change with time . Using vibration for fault inspection requires understanding of multidisciplinary research fields. To minimize the costs induced by unexpected failure, the need for continuous structural health monitoring is increasing . The vibration was also used to monitor the health of composite laminate structures. The natural frequency, damping, mode shapes curvature, transfer function and frequency response are used to analyze the transient responses. Defects have been diagnosed by using the time of flight for the propagation of a high-frequency guided wave transmitted to a structure. Low-frequency vibration has disadvantages for localization because the entire structure is excited . [4]

Vibration signals analysis also has some advantages and disadvantages. Real-time machine and structure monitoring can be achieved using vibration analysis and there are many well-developed signal processing techniques that can be applied. The limitations of vibration analysis are noise contamination and proper mounting position of the vibration sensors . [5]

To measure this Vibration there is a equipment called Vibrometer . It is the equipment that I s used to measure the vibration of machine as frequency in Hz or RPM . This device can also measure the vibration level of power generating set . [1]

There is a most frequently used word vibration .

1.2 Vibration

Vibration is an oscillatory motion of a particle or body about a fixed equilibrium point . Vibration is the most well known secondary signal in most of the structures and machine . Vibration is the movement of body or object back and forth from its position of rest or neutral and it is considered in displacement mode , frequency mode and acceleration mode .

Vibration in any structure or machine can be characterized by :

I. The frequency in Hz or Revolution per Minute (RPM)
II. The amplitude of the Measured parameter.

And the unit of vibration depends upon the following parameters:

I. Acceleration , measured in m/s^2
II. Velocity , measured in m/s
III. Displacement , measured in m.

This vibration causes many adverse effect in the machine or structure like wear and tear , crack , fatigue , failure etc , as well as in the human beings like motion sickness , breathing , speech disturbance , white finger disease etc . [1]

Vibration can be desirable in some cases such as the motion of a tuning fork, the reed in a woodwind instrument or harmonica, a mobile phone, or the cone of a loudspeaker. But in most of the cases vibration is undesirable and causes destruction and malfunctioning of machine or structure , such as , the vibrational motions of engines, electric motors, or any mechanical device in operation are typically unwanted. Such vibrations could be caused by imbalances in the rotating parts, uneven friction, or the meshing of gear teeth. [6]

Vibration are of various types some of most common types of vibrations are :

I. Free Vibration : Vibration of a system because of its own elastic property. No external force is required for this vibration and only initiation of vibration may be necessary.
II. Forced Vibration : A system that vibrates under an external force at the same frequency as that of external force.
III. Damped Vibration : When the energy of a vibrating system is gradually dissipated by friction and other resistances, the vibrations are said to be damped. The vibrations gradually reduce or change in frequency or intensity or cease and the system rests in its equilibrium position. An example of this type of vibration is the vehicular suspension dampened by the shock absorber.[7]

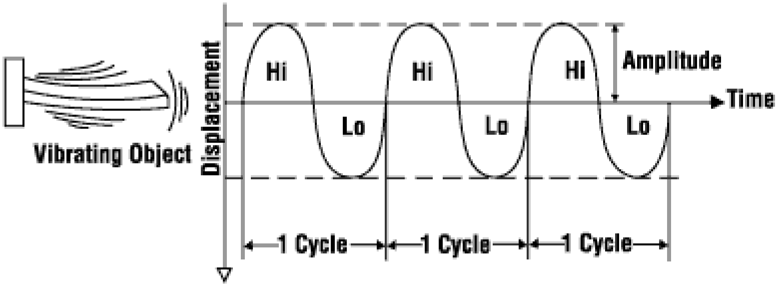

Fig 01 [8] Vibration

1.2.1 **Vibration isolation**

Vibration isolation is the process of isolating an object, such as a piece of equipment, from the source of vibrations.

Vibration is undesirable in many domains, primarily engineered systems and habitable spaces, and methods have been developed to prevent the transfer of vibration to such systems. Vibrations propagate via mechanical waves and certain mechanical linkages conduct vibrations more efficiently than others. Passive vibration isolation makes use of materials and mechanical linkages that absorb and damp these mechanical waves. Active vibration isolation involves sensors and actuators that produce disruptive interference that cancels-out incoming vibration.[7] There are various types of isolators, including metal springs, rubber mounts, and pneumatic mounts. Vibration isolation can be achieved by using materials capable of providing a combination of highly elastic behavior in conjunction with damping properties. [9]

1.2.2 Causes of Structural vibration

Structural vibration occurs when dynamic forces generated by compressors, pumps, and engines cause the deck beams to vibrate. This vibration leads to piping failures, poor equipment reliability, and safety concerns. The vibration is due to the structure being mechanically resonant.[10]

Structural vibration is one of the most common and big issue that is faced by any buildings or bridges . generally this vibration occurs due to the seismic forces or human made sources such as crowd movement , traffic, blasting, heavy machine operations etc. This can affect the strength of structures or even leads to failure or collapse of the structure itself.[11]

There are a variety of sources can be found for vibrations which affect buildings or structures. This can be listed as follows:

Internal sources

1 Working of heavy machinery (inside or outside the building)

2 Crowd activities (walking, dancing, running etc.)

External sources

1 Seismic forces

2 Traffic movement (Railways, vehicles, subways)

3 Construction activities

4 Wind forces etc.

While designing buildings or structures it is important to ensure that the structural members are capable of resisting these forces and prevent fatigue due to this cyclic loading. From the above sources, seismic forces and wind forces are very critical.[11]

1.2.3 Effects of Structural vibration

The vibrations can transfer through soil (if it is an external source) and propagate through foundation, walls, floors etc. of buildings and can cause cracks in concrete, bricks, or other masonry structures etc.

In extreme cases, the vibrations may cause damage to the structures. When cyclic loading is repeated that may cause strength loss and even leads to fatigue failure. If the vibrations coincide (matches) with the natural frequency of the structure resonance occurs which induces vibratory motion in higher amplitude. Rigid components generally affected than flexible components in structures due to vibrations . In the case of old structures, they have less strength or tolerance compared to structures in the modern era. That makes old structures are very sensitive to vibrations. In old structures, the cyclic vibrations can easily crack the brittle elements and lead to structural instability . The vibration induced by traffic can cracks the building walls or ceiling or even foundation too. The traffic vibration is; commonly varies in between 5Hz to 25Hz. If a structures is subjected to traffic vibration for many years fatigue damage can occur also sometimes soil settlement can happen (mostly in sandy soil) and that leads to uneven movement of structures . Vibration control is very important for the stability and durability of a building or structures. But unfortunately, there is not giving much importance to vibration control in structure . [11]

Yet vibration can be desirable as well as undiserable . Some pros and cons of vibration are

Pros :

1. Vibrations are responsible to simulate earthquakes for geological investigations .
2. Vibrations is used for drilling of geo – technical wells.
3. Vibrations are also responsible in agriculture for harvesting by forced vibrations of fruits bearing trees.
4. In many big structures vibrations are responsible to settle down the gaps that occurs during building of the structures.[12]

Cons :

1. Unwanted Vibrations produces unpleasant stresses in the machine and structure parts.
2. Many structures , buildings and bridges falls down and get destructed due to vibrations.
3. The vibration causes rapid wear and damages in machine parts and structures such as bearing and gears.
4. Excessive vibration is also dangerous and harmful for human beings.[12]

We have talked a lot about vibration now there is a need to know how to measure this vibration . Vibrometer is the equipment that is used to measure the vibration .

1.3 Vibrometer

Vibrometer is the device that is used to measure the amount of vibration generated in any machine or structure.[1] Vibrometers are the portable devices which, thanks to various vibration detection methods – based on accelerometers or laser technology – measure the vibration level of a machine or structures and its components. It is a reflection of the technical condition, and its thorough analysis makes it possible to diagnose the defects or wear of bearings, determine possible misalignment or asymmetry, and detect plays or throws in machine and damages in structures . A modern vibrometer saves all the data in its memory and then sends it to a PC or a mobile device equipped with dedicated analysis and archiving software.[13]

Vibrometer are generally based on two types : Vibrometer based on accelerometer and laser Vibrometer .

In our project we have used laser vibrometer to detect the vibration in a structure or machine .

Laser vibrometers employ completely different technology. Their operation consists in detecting and analysing laser radiation, which is dispersed on a vibrating part of the machine. A well-known phenomenon called the Doppler effect is applied here: when an object vibrates, then the frequency of light changes and the measurement of the difference in frequencies becomes the basis for calculating the speed of movement of the examined object, the amplitude of its vibrations or acceleration.[13]

1.3.1 Laser Doppler Vibrometer (LDV)

A **laser Doppler vibrometer** (**LDV**) is a scientific instrument that is used to make non-contact vibration measurements of a surface. The laser beam from the LDV is directed at the surface of interest, and the vibration amplitude and frequency are extracted from the Doppler shift of the reflected laser beam frequency due to the motion of the surface. The output of an LDV is generally a continuous analog voltage that is directly proportional to the target velocity component along the direction of the laser beam.

Some advantages of an LDV over similar measurement devices such as an accelerometer are that the LDV can be directed at targets that are difficult to access, or that may be too small or too hot to attach a physical transducer. Also, the LDV makes the vibration measurement without mass-loading the target. [14]

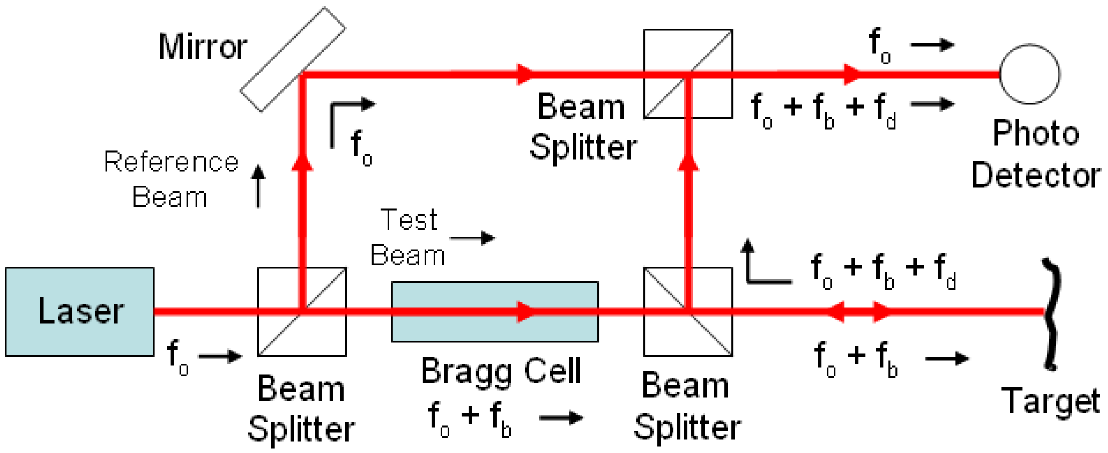

Fig 02 [15] Components of Laser Doppler Vibrometer (LDV)

Principle of operation of LDV : A vibrometer is generally a two beam laser interferometer that measures the frequency (or phase) difference between an internal reference beam and a test beam. The most common type of laser in an LDV is the helium–neon laser, although laser diodes, fiber lasers, and Nd:YAG lasers are also used. The test beam is directed to the target, and scattered light from the target is collected and interfered with the reference beam on a photodetector, typically a photodiode. Most commercial vibrometers work in a heterodyne regime by adding a known frequency shift (typically 30–40 MHz) to one of the beams. This frequency shift is usually generated by a Bragg cell, or acousto-optic modulator.[1]

A schematic of a typical laser vibrometer is shown above. The beam from the laser, which has a frequency f_o, is divided into a reference beam and a test beam with a beamsplitter. The test beam then passes through the Bragg cell, which adds a frequency shift f_b. This frequency shifted beam then is directed to the target. The motion of the target adds a Doppler shift to the beam given by $f_d = 2*v(t)*\cos(\alpha)/\lambda$, where v(t) is the velocity of the target as a function of time, α is the angle between the laser beam and the velocity vector, and λ is the wavelength of the light.

Light scatters from the target in all directions, but some portion of the light is collected by the LDV and reflected by the beamsplitter to the photodetector. This light has a frequency equal to $f_o + f_b + f_d$. This scattered light is combined with the reference beam at the photo-detector. The initial frequency of the laser is very high (> 10^{14} Hz), which is higher than the response of the detector. The detector does respond, however, to the beat frequency between the two beams, which is at $f_b + f_d$ (typically in the tens of MHz range).

The output of the photodetector is a standard frequency modulated (FM) signal, with the Bragg cell frequency as the carrier frequency, and the Doppler shift as the modulation frequency. This signal can be demodulated to derive the velocity vs. time of the vibrating target.

1.4 Cantilever beam

A cantilever beam is an inflexible structural component held at one end and free at the other end. The cantilever beam can be either prepared of concrete or steel whose one end is bound or tied up to a vertical support. It is a horizontal beam structure whose free end is opened to vertical loads.

In any structure, a cantilever is built as an addition to a continuous beam, and in bridges, it is a part of a cantilever girder. It can be built either cast-in-situ or by dividing construction by pre-stressing methods . Cantilever construction permits overhanging structures without extra supports and bracing. This structural component is majorly utilized in the construction of bridges, towers, and buildings, and can attach a special appearance to the structure . [16]

1.4.1 Design of Cantilever Beam

A cantilever beam under the action of the structural load is put through the moment and shear stresses. The aim of any design process is to transfer these stresses safely to the support .The bending moment of a cantilever beam differs from zero at the free end to the highest value at the fixed end support. Hence during the preparation of cantilever beams, the major reinforcement is given to the upper fibre of the concrete beam to resist the tensile stress safely.

The major span of a cantilever beam is reliable on the following factors noted below:

1. The depth of the cantilever
2. The magnitude, type, and location of the load.
3. The quality and type of material used

1.4.2 Application of cantilever Beam

Some of the applications of Cantilever Beam are :

1. Construction of cantilever beams and balconies
2. Temporary cantilever support structures
3. Freestanding radio towers without guy wire
4. Construction of cantilever beam for pergolas
5. Lintel construction in buildings.

1.4.3 Advantages of Cantilever Beam

The important advantages of cantilever beams are:

1. Cantilever beams do not need any support on the other end.
2. The negative bending moment raised in cantilever beams use to prevent the positive bending moments raised.
3. Cantilever beams can be easily built.[16]

1.4.4 Disadvantages of Cantilever Beam

The disadvantages of cantilever beams are:

1. Cantilever beams are put through huge deflections.
2. Cantilever beams are put through larger moments.
3. Strong fixed support or a back span is needed to make the structure balance.[16]

1.5 Vibration Signal Analysis of Cantilever Beam using Machine Learning Algorithms

Vibrations are common phenomena seen in mechanical structures that can be detrimental to many systems. If not monitored, they can cause damage to structures, Vibrometer is sensor used for measuring vibrations of mechanical structures, machines, as well as sound level in an area and will collect lot of data that is to be analyzed to determine the strength of the structures. Machine learning is the basic working technology for prediction and determining the work proposes system aims to predict the health of a structure, converting the cantilever beam vibration reading to graph which is able to give the correct state or health of the structure. This work will cover all the major challenges faced due to natural down fall of quality of structure .The aims to able to check the Structural Health and able predict the condition of the structure .

Vibration is a phenomenon where the oscillation takes place at the equilibrium point . The term vibration stands for Shaking ,brandishing . the Vibration are the singles consisting of number of frequencies , the reading of data set are pure reading in the time domain , which are required to be converted into frequency domain .

Cantilever Beam is a type of beam with one end projecting ahead the point of support ,this beam is free to move in a vertical plane under the influence of loads placed the free end and the support . This beam is generally small and is restricted to 2m to 3m . Vibrometer is a two-beam laser measuring device used for measuring frequency difference between the internal refence beam and a test beam. the use of this device is to measure vibration amplitude. Automation System is the demand and requirement of the future.

The system is the graphical representation of the vibrometer, the beam is the combination of two, infrared LDV and He-Ne SLDV from the target. . The reading of the vibrometer is in continuous numerical and in the time domain the domain required is frequency. the signal are vibrations and it requires a converter to convert the signal into binary which are understood by the computer system.

Fig 03 [17] Vibrometer

We are expecting a system that is used to measure the amount of vibration in a cantilever beam using various machine learning algorithm and give the life span of any given structure. If the vibrometer is reading any input of vibration from a structure and it is coming within a specific range than the structure is free from destruction and if the vibration level is higher than the specific range that there is fault in the structure and it can be damaged and there is high risk of destruction of that structure . In this case there is a need of machine learning algorithm to be implemented so that there will be prior information regarding the damage and it will be free from the damage.

The original vibration in Cantilever beam that is detected through the vibrometer is in the time domain and to implement it in the real world we need to convert it into the frequency domain . And this conversion of time domain into the frequency domain is done with the help of Fast Fourier Transform (FFT) analyzer .

The original dataset is in time domain

Source	CH1
Second	Volt
-0.8192	-9.8
-0.81912	-9.8
-0.81904	-9.8
-0.81896	-9.8
-0.81888	-9.8
-0.8188	-9.8
-0.81872	-9.8
-0.81864	-9.8
-0.81856	-9.8
-0.81848	-9.8
-0.8184	-9.8
-0.81832	-9.8
-0.81824	-9.8
-0.81816	-9.8
-0.81808	-9.8
-0.818	-9.8
-0.81792	-9.8
-0.81784	-9.8
-0.81776	-9.8

Fig 04 [17] original dataset in Time domain

Converted datset into frequency domain :

	A	B	C	D	E	F
1	Source		CH1			
2	Second	f=1/sec	Volt	amp		
3	-0.8192	-1.2207	-9.8	-4.9		
4	-0.81912	-1.22822	-9.8	-4.9		
5	-0.81904	-1.229	-9.8	-4.9		
6	-0.81896	-1.22106	-9.8	-4.9		
7	-0.81888	-1.22118	-9.8	-4.9		
8	-0.8188	-1.2213	-9.8	-4.9		
9	-0.81872	-1.22141	-9.8	-4.9		
10	-0.81864	-1.22154	-9.8	-4.9		
11	-0.81856	-1.22166	-9.8	-4.9		
12	-0.81848	-1.22178	-9.8	-4.9		
13	-0.8184	-1.2219	-9.8	-4.9		
14	-0.81832	-1.22202	-9.8	-4.9		
15	-0.81824	-1.22214	-9.8	-4.9		
16	-0.81816	-1.22225	-9.8	-4.9		
17	-0.81808	-1.22237	-9.8	-4.9		
18	-0.818	-1.22249	-9.8	-4.9		
19	-0.81792	-1.22261	-9.8	-4.9		
20	-0.81784	-1.22273	-9.8	-4.9		
21	-0.81776	-1.22285	-9.8	-4.9		
22	-0.81768	-1.22297	-9.8	-4.9		

Fig 05 [17] converted dataset in frequency domain

1.5.1 Time Domain Analysis

The simplest vibration analysis for machine diagnosis is used to analyze the measured vibration signal in the time domain. Vibration signals obtained are a series of values representing proximity, velocity, and acceleration, and in time domain analysis, the amplitude of the signal is plotted against time. Although other sophisticated time domain approaches have been used, the approach of visually looking at the time waveform should not be underestimated because numerous information can be obtained in this manner. This information includes the presence of amplitude modulation, shaft unbalance, transient, and higher-frequency components . However, simply looking into these vibration signals cannot segregate the variations in vibration signals for different machine failures due to the noisy data, especially at the early stage of failure. Thus, a signal processing method is required to obtain the important information from the time domain signals by converting the raw signals into appropriate statistical parameters such as peak, RMS, crest factor, and kurtosis. Several statistical parameters are usually extracted from the time domain signal so that the most significant parameter, which can effectively differentiate between healthy and defective machine vibration signals, can be chosen .[18]

1.5.2 Frequency Domain Analysis

Most real-world signals can be broken down into a combination of unique sine waves. Each sine wave will appear as a vertical line in the frequency domain, where the height and position of the line represent the amplitude and frequency, respectively. In frequency domain analysis, the amplitude is plotted against frequency and compared to the time domain, and the detection of the resonant frequency component is easier. This is one of the reasons why frequency domain methods are favorable in detecting faults in the machine . Several characteristics of the signal that are not visible in the perspective of time domain can be observed using frequency domain analysis.[18]

1.5.3 Time Frequency Domain Analysis

Time and frequency domains are integrated into the time-frequency domain analysis. This means that the signal frequency component and their time-variant features can be determined simultaneously in this analysis. Vibration analysis approaches mentioned before (time domain and frequency domain methods) mostly rely on the stationary assumption that is unable to detect the local features in time and frequency domain simultaneously.[18]

For converting this time domain data to frequency domain we use the concept of FFT that will convert the time domain to frequency domain.

1.5.4 Fast Fourier Transform (FFT) Analyzer

Fast Fourier transform (FFT) converts a signal in the time domain to the frequency domain, generating the spectrum .

FFT is an efficient and widely used algorithm to obtain the FT of discretized time signals. The FFT plot of fault-free industrial machines consists of only one peak, which represents the natural frequency of the operating machine. Thus, defect in the machine can be identified when there is a presence of other peaks aside from the natural frequency peak in the plot. It is the quickest way to separate the frequencies of the signal for the diagnosis process. A combination of time domain signal analysis and FFT is normally associated with diagnosing the low-speed machine to produce more accurate results but the major concern is its reliance on the magnitude of the fault having an effect on the carrier frequency. [18]

A fast Fourier transform can be used in various types of signal processing. It may be useful in reading things like sound waves, or for any image-processing technologies. A fast Fourier transform can be used to solve various types of equations, or show various types of frequency activity in useful ways. fast Fourier transform and the DFT are largely the province of engineers and mathematicians looking to change or develop elements of various technologies.[19]

FT is given by :

$$F(\omega) = Ff(t) = \int_{-\infty}^{\infty} f(t)\, e^{-i\omega t} \mathrm{d}t.$$

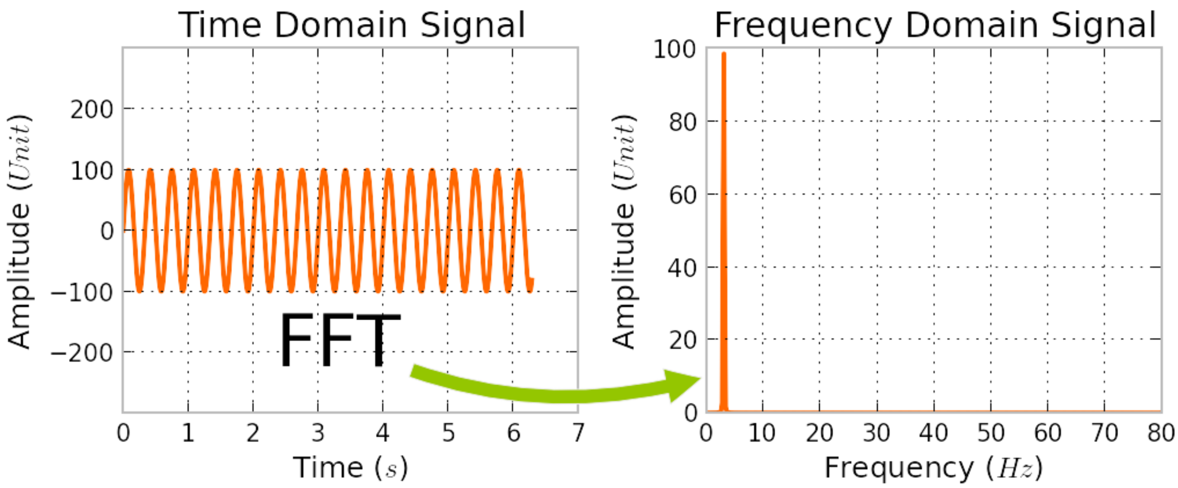

Fig 06 [20] Conversion of Time domain into Frequency domain Using FFT

To implement Vibration signal analysis in Cantilever beam we use the technology of machine learning. As machine learning is the fast growing technology and can be used to build various model that can predict an idea of what will happen further . to implement this in real time we will train the data by giving majority of the data and than test the data by giving any real time input . To implement this firstly lets know about the machine learning and Artificial Intelligence.

Machine learning is the subset of Artificial Intelligence that is machine learning comes under Artificial Intelligence hence knowledge of AI will make better understand about Machine Learning(ML).

1.6 Artificial Intelligence

Artificial Intelligence is a method of making a computer, a computer-controlled robot, or a software think intelligently like the human mind. AI is accomplished by studying the patterns of the human brain and by analyzing the cognitive process. The outcome of these studies develops intelligent software and systems.

1.6.1 How Does Artificial Intelligence Work?

AI systems work by merging large with intelligent, iterative processing algorithms. This combination allows AI to learn from patterns and features in the analyzed data. Each time an Artificial Intelligence system performs a round of data processing, it tests and measures its performance and uses the results to develop additional expertise .[21]

1.6.2Ways of Implementing AI

- **Machine Learning:** It is machine learning that gives AI the ability to learn. This is done by using algorithms to discover patterns and generate insights from the data they are exposed to.

- **Deep Learning:** Deep learning, which is a subcategory of machine learning, provides AI with the ability to mimic a human brain's neural network. It can make sense of patterns, noise, and sources of confusion in the data.[21]

For Implementing Vibration signal analysis in Cantilever beam machine learning is used .

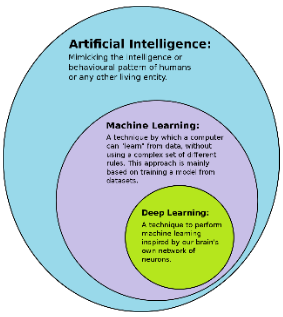

Fig 07 [22] Subset of Artificial Intelligence

1.7 Machine Learning

Machine Leaning is the part of Artificial Intelligence **which enables the machine to automatically learn from data, improve performance from past experiences, and make predictions.** Machine learning contains a set of algorithms that work on a huge amount of data. Data is fed to these algorithms to train them, and on the basis of training, they build the model & perform a specific task.[23]

Machine learning algorithms build a model based on sample data, known as training data, in order to make predictions or decisions without being explicitly programmed to do so. Machine learning algorithms are used in a wide variety of applications, such as in medicine, email filtering, speech recognition, and computer vision, where it is difficult or unfeasible to develop conventional algorithms to perform the needed tasks.

Machine learning approaches are traditionally divided into three broad categories, which correspond to learning paradigms, depending on the nature of the "signal" or "feedback" available to the learning system:

1. Supervised learning: The computer is presented with example inputs and their desired outputs, given by a "teacher", and the goal is to learn a general rule that maps inputs to outputs.
2. Unsupervised learning: No labels are given to the learning algorithm, leaving it on its own to find structure in its input. Unsupervised learning can be a goal in itself (discovering hidden patterns in data) or a means towards an end (feature learning).
3. Reinforcement learning: A computer program interacts with a dynamic environment in which it must perform a certain goal (such as driving a vehicle or playing a game against an opponent). As it navigates its problem space, the program is provided feedback that's analogous to rewards, which it tries to maximize. [24]

1.7.1 Supervised Learning

Supervised Learning is based on supervision. It means in the supervised learning technique, we train the machines using the labelled dataset, and based on the training, the machine predicts the output. Here, the labelled data specifies that some of the inputs are already mapped to the output. More preciously, we can say; first, we train the machine with the input and corresponding output, and then we ask the machine to predict the output using the test dataset.

Supervised machine learning can be classified into two types of problems, which are given below:

1. Classification
2. Regression

Classification : Classification algorithms are used to solve the classification problems in which the output variable is categorical, such as "Yes" or No, Male or Female, Red or Blue, etc. The classification algorithms predict the categories present in the dataset. Some real-world examples of classification algorithms are Spam Detection, Email filtering, etc.

Some popular classification algorithms are given below:

1. Random Forest Algorithm
2. Decision Tree Algorithm
3. Logistic Regression Algorithm
4. Support Vector Machine Algorithm

Regression : Regression algorithms are used to solve regression problems in which there is a linear relationship between input and output variables. These are used to predict continuous output variables, such as market trends, weather prediction, etc.

Some popular Regression algorithms are given below:

1. Simple Linear Regression Algorithm
2. Multivariate Regression Algorithm
3. Decision Tree Algorithm
4. Lasso Regression

1.7.2 Unsupervised Learning

Unsupervised learning is different from the Supervised learning technique; as its name suggests, there is no need for supervision. It means, in unsupervised machine learning, the machine is trained using the unlabeled dataset, and the machine predicts the output without any supervision .In unsupervised learning, the models are trained with the data that is neither classified nor labelled, and the model acts on that data without any supervision.

Unsupervised Learning can be further classified into two types, which are given below:

1. **Clustering**
2. **Association**

Clustering : The clustering technique is used when we want to find the inherent groups from the data. It is a way to group the objects into a cluster such that the objects with the most similarities remain in one group and have fewer or no similarities with the objects of other groups. An example of the clustering algorithm is grouping the customers by their purchasing behaviour.

Some of the popular clustering algorithms are given below:

1. K-Means Clustering algorithm
2. Mean-shift algorithm
3. DBSCAN Algorithm
4. Principal Component Analysis
5. Independent Component Analysis

Association : Association rule learning is an unsupervised learning technique, which finds interesting relations among variables within a large dataset. The main aim of this learning algorithm is to find the dependency of one data item on another data item and map those variables accordingly so that it can generate maximum profit. This algorithm is mainly applied in **Market Basket analysis, Web usage mining, continuous production,** etc.

Some popular algorithms of Association rule learning are **Apriori Algorithm, Eclat, FP-growth algorithm.**

In Vibration signal analysis in cantilever beam supervised machine learning algorithm is applied as data is labelled . Vibration data is accompanied with output is under the Supervised Learning and the data is non-linear thus Support Vector Machine(SVM) will produce the most relevant result . [23]

1.7.3 Support Vector Machine (SVM)

The method of supervised learning like Support Vector Machine (SVM) and proximal support Vector Machines (PSVM) have been used in many applications of machine learning because of its high accuracy and good generalization capabilities. SVM is based on statistical learning theory. SVM classifies better than ANN because of the principle of risk minimization.[25]

This method transforms the data set or sample space to a high-dimensional, kernel-induced feature space by nonlinear transformation and then determines the best hyperplane . The best hyperplane means the one with the largest margin between the two classes . One of the reasons why SVM is widely applied in vibration analysis for machine diagnosis is due to its compatibility with large and complex datasets such as data collected in the manufacturing industry. SVM is very useful as the number of features of classified entities will not affect the performance of SVM. This means that for the base of the diagnosis system, there is no limited number of attributes that can be selected. There is no requirement for experts' knowledge in SVM, as is the case with fuzzy logic, and no layers are involved in SVM structure, compared to NN.[18]

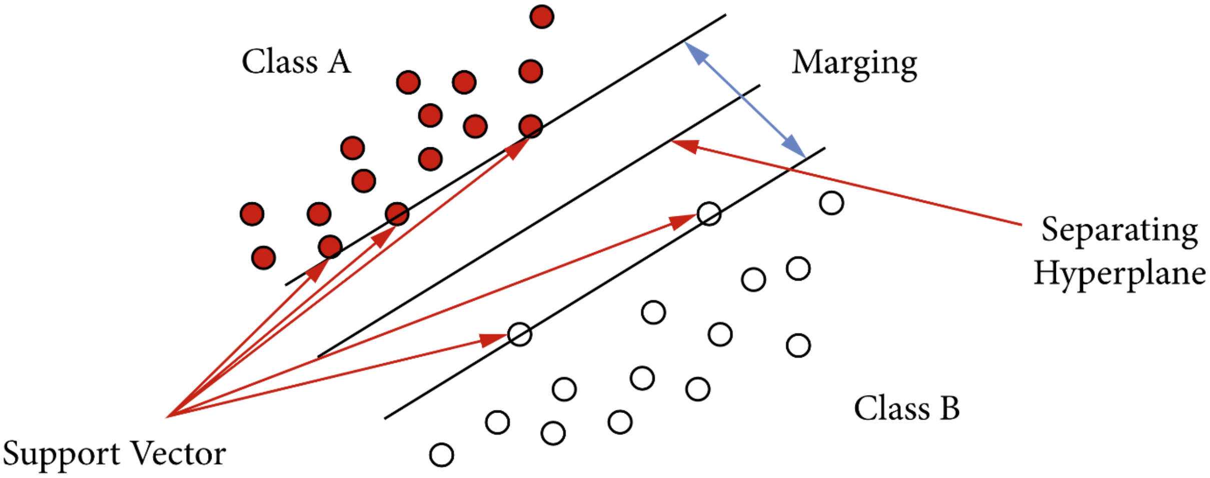

Fig 08 [26] The structure of SVM technique.

1.7.3.1 Advantages of using SVM Algorithm in Vibration Analysis

1. Being a highly sophisticated and mathematically sound algorithm, it is one of the most accurate machine learning algorithms.
2. It is a dynamic algorithm and can solve a range of problems, including linear and non-linear problems, binary, binomial, and multi-class classification problems, along with regression problems.
3. SVM uses the concept of margins and tries to maximize the differentiation between two classes; it reduces the chances of model overfitting, making the model highly stable.

4. SVM is known for its computation speed and memory management. It uses less memory, especially when compared to machine vs deep learning algorithms with whom SVM often competes and sometimes even outperforms to this day.[27]

In this project SVM Machine learning algorithm has been used and it is best suited for the dataset and we are using SVM because text is given as a input to the machine but if in future we use image as a input than it will be much better and advance version of this project so for using image as an input , here Convolutional Neural Network (CNN) algorithm of deep learning will be used .

Chapter 2

Literature Survey

Sharma Jai Kumar [28]The study in [28] covered that the Laser Vibrometer through which beam reading are obtained even the shapes too boundary, the nature of beam is free, the nature of reading is in the time domain the domain to which it should or required to be converted is frequency. Vibration analysis of the beam using experimental modal analysis is the process to determine the modal parameters in the form of natural frequency, mode shape, and damping. It has also covered a theoretical, experimental, and numerical modal analysis of beam in free-free and simply supported boundary condition. The experimental modal analysis (EMA) of the beam excited using impact hammer is performed with the help of a Laser Vibrometer. The use of MATLAB environment for programming , signal from time domain to frequency domain is converted into the frequency domain using Fast Fourier Transform (FFT). The finite element modeling (FEM) software, ANSYS workbench 14.5, performed the numerical modal analysis of beam, .The obtained natural frequency and mode shapes of the free-free and simply supported beam are compared with results obtained through theoretical. The comparison of all three results, i.e., theoretical results, numerical results, and experimental results shows that the results are all well within the reasonable error margin. The study and result will provide researchers and engineers for the better design and development of engineering components. The experiment was not possible to excite the third mode in simply supported boundary condition. Similarly, the fourth and higher modes cannot be excited in freefree boundary conditions of the beam using the impact hammer. For determination of higher modes, the sine sweep test can be more effective. The experimental and numerical results for the beam are found to have an extremely good correlation. Some error between the results is also introduced by physical dimensions of beam and variation of Young's modulus. analysis describes that the results are all well within the reasonable error margin. The modal analysis techniques presented in this paper may be helpful in dynamic analysis, developing and optimizing the design of complex engineering structure and components .

Henri J. Nussbaumer [29] The software used for analysis of FFT Fast Fourier Transform is FEM Finite Element Model.The experimental and numerical model also covered the accurate boundary conditions and the determined results have certain errors with the real result. The outcomes from this article covered are Nature of Beam, Nature of frequency, software used for analysis of FFT, FEM. The drawback or the area to be included in these the changing methods or how the conversion took place and it is difficult to convert one domain to other domain without proper knowledge The conversion of the beam reading, Shape boundary reading should also be done so the analysis and unit reading will become more understandable and the outcome will become more efficient after we convert these readings . .It covers the summarization of the main properties of the discrete Fourier transform (DFT) and to present various fast DFT computation techniques known collectively as the fast Fourier transform (FFT) algorithm. The DFT is important as it can be used as a mathematical tool to describe the relationship between the time domain and frequency domain representation of discrete signals. The use of DFT analysis methods has increased dramatically since the introduction of the FFT in 1965 because the FFT algorithm decreases by several orders of magnitude the number of arithmetic operations required for DFT computations. It has thereby provided a practical solution to many problems that otherwise would have been intractable.

The Discrete Fourier transform[30] (converts a finite sequence of equally-spaced samples of a function into a same-length sequence of equally-spaced samples of the discrete-time Fourier transform (DTFT), which is a complex-valued function of frequency. The interval at which the DTFT is sampled is the reciprocal of the duration of the input sequence. An inverse DFT is a Fourier series, using the DTFT samples as coefficients of complex sinusoids at the corresponding DTFT frequencies. It has the same sample-values as the original input sequence. The DFT is therefore said to be a frequency domain representation of the original input sequence. If the original sequence spans all the non-zero values of a function, its DTFT is continuous (and periodic), and the DFT provides discrete samples of one cycle. If the original sequence is one cycle of a periodic function, the DFT provides all the non-zero values of one DTFT cycle.

The DFT is the most important discrete transform, used to perform Fourier analysis in many practical applications. In digital signal processing, the function is any quantity or signal that varies over time, such as the pressure of a sound wave, a radio signal, or daily temperature readings, sampled over a finite time interval (often defined by a window function). In image processing, the samples can be the values of pixels along a row or column of a raster image. The DFT is also used to efficiently solve partial differential equations, and to perform other operations such as convolutions or multiplying large integers.

Since it deals with a finite amount of data, it can be implemented in computers by numerical algorithms or even dedicated hardware. These implementations usually employ efficient fast Fourier transform (FFT) algorithms; so much so that the terms "FFT" and "DFT" are often used interchangeably. Prior to its current usage, the "FFT" initialism may have also been used for the ambiguous term "finite Fourier transform".

Seppe Sels ,BartRibbens, BorisBogaerts ,Jeroen Peeters ,Steve Vanlanduit [[31]The approach in [31]has the properties of the PSV-3D Scanning Vibrometer with robotics and makes it viable to utilize CAE Computer Aided Engineering data for defining the test. The main advantage for the model updating process. is the potential to work with imported Finite Element geometries and coordinate systems and to automatically gather data at all nodal points. Use of robotics is after the successful steps and after the model is working virtually then connecting IOT and robotics come into picture. The work that needed to be done is the data that is being gather from the nodal point of the beam should be observed carefully and made it very sure the reading should in the domain frequency format automatically before the modelling into 3D Scanning as the frequency domain have or accurate results in 3D modelling the new fully automated scanning laser Doppler vibrometer (LDV) measurement technique is presented. In contrast to existing scanning LDV techniques which use a 2D camera for the manual selection of sample points, use a 3D Time-of-Flight camera in combination with a CAD file of the test object to automatically obtain measurements at pre-defined locations. The proposed procedure allows users to test prototypes in a shorter time because physical measurement locations are determined without user interaction. Another benefit from methodology is that it incorporates automatic mapping between a CAD model and the vibration measurements. This mapping can be used to visualize measurements directly on a 3D CAD model. The proposed method is illustrated with vibration measurements of an unmanned aerial vehicle .

3D time of flight (ToF) is a type of scanner-less LIDAR (light detection and ranging) that uses high power optical pulses in durations of nanoseconds to capture depth information (typically over short distances) from a scene of interest.

ADI offers industry-leading products and solutions that enable and enhance industry-leading performance for ToF systems and cameras, including the highest resolution CMOS imaging chips (1 Megapixel), depth computation and processing, laser drivers, and power management, along with development tools and software/firmware to aid in the quick implementation of ToF solutions. In addition, ADI helps facilitate quick time-to-revenue by leveraging a global partner network in developing ToF modules, cameras, and design services.

- .A new fully automatic scanning methodology for measuring vibrations is proposed.
- The methodology uses a 3D camera and a 3D CAD-file in combination with a scanning laser Doppler vibrometer.
- 3D pose estimation techniques are used to find a predefined sample-object and automatically select sample points.

Haus, Jan Niklas, Walter Lang, Thomas Roloff, Liv Rittmeier, Sarah Bornemann, Michael Sinapius, and Andreas Dietzel [32] The graphene NEMS is working in a resonate mode which can be used for high performance of vibration sensors, the device is not able to predict the vibration value as expected but it does provide some fundamental effect with greater impact on device with high quality and have a very low stress. The idea or thing to overcome is the prediction value should be correct for the model to work according it, the values or reading must be accurate according to the resonant. Microelectromechanical systems (MEMS) proposed by authors of is a Structural Health Monitoring system, the lightweight construction build of material on which the Structural Monitoring System, this based on certain frequency to check the health, the frequency of 100kHz at a certain distance of 0.2m. The issue here is certain material which are not lightweight does not pass the ultra sound wave so no result check can be done. Structural health monitoring of lightweight constructions made of composite materials can be performed using guided ultrasonic waves. If modern fibre metal laminates are used, it requires integrated sensors that can record the inner displacement oscillations caused by the propagating guided ultrasonic waves. Therefore, we developed a robust MEMS vibrometer that can be integrated while maintaining the structural and functional compliance of the laminate. This vibrometer is directly sensitive to the high-frequency displacements from structure-borne ultrasound when excited in a frequency range between its first and second eigenfrequency. The vibrometer is mostly realized by processes earlier developed for a pressure sensor but with additional femtosecond laser ablation and encapsulation. The piezoresistive transducer, made from silicon, is encapsulated between top and bottom glass lids. The eigenfrequencies are experimentally determined using an optical micro vibrometer setup. The MEMS vibrometer functionality and usability for structural health monitoring are demonstrated on a customized test rig by recording application-relevant guided ultrasonic wave packages with a central frequency of 100 kHz at a distance of 0.2 m from the exciting ultrasound transducer. A characterization of the sensitivity and the signal-to-noise-ratio will be addressed ,using a tailored characterization environment with longer propagation distance that wasvery recently established . Further, sensor damping adjustment will be possible by entrapping gas of defined pressure inside the sensor cavity. GUW-based SHM will be performed using FML-embedded MEMS vibrometers with improved resonators. In future work, an integrable sensor data acquisition nodewill be used to wirelessly power the vibrometer and read its GUW signals.

(MEMS vibrometer; structural health monitoring (SHM); guided ultrasonic waves (GUW);

fiber metal laminates (FML))

MEMS vibrometer micro **e**lectro **m**echanical **s**ystems

Zhang, Chunwei, Asma A. Mousavi, Sami F. Masri, Gholamreza Gholipour, Kai Yan, and Xiuling Li[33] The Non-Linear data under the Supervised learning where the data does not follow any particular trend thus the use of classification algorithm of Supervised learning i.e is SVM , Support Vector Machine is best suitable with the data set used , the SVM will able to predict the accurate result of the dataset . If the dataset belong to the category , like images , the deep learning and neural networks combined with Open cv and image processing methods of AI to included for performance measurement and predicting the result , CNN is the best suitable for image data , CNN is Convolution Neural Networks. Structural health monitoring (SHM) has become an important and hot topic for decades in various fields of civil, mechanical, automotive, and aerospace engineering, etc. Estimating the health condition and understanding the unique characteristics of structures through assessing measured physical parameters in real-time is the major objective of SHM. As a result, signal processing becomes an essential and inseparable approach of vibration based SHM research. The basic goal of using signal processing is to identify the changes or damages from the vibration signals of the dynamic system to detect, locate, and quantify any damages existing in the system. This paper aims to present a comprehensive review of the recent progress that used signal processing techniques for vibration based SHM approaches. Furthermore, the feature extraction process through the signal processing techniques is the basic skeleton of this review. The application of signal processing techniques in structural damage identification procedure is classified into two approaches, namely (i) time-domain and (ii) frequency-domain. Experimental studies have assessed the potentials of the signal processing techniques in two aforementioned domains to enhance the vibration-based structural damage detection subjected to environmental effects. While there have been multiple review studies published on vibration-based structural damage detection, there exists no study in categorizing the signal processing techniques based on the feature extraction procedure that belongs to time and frequency domains for SHM purposes. This review fills this gap and presents a holistic summary of the cutting-edge methodology and technique applied in the relevant research field.

a. A comprehensive review is presented on the vibration-based signal processing techniques for dynamic feature extraction of structures.

b. The signal processing techniques is categorized based on their representations in time and frequency domains.

c. The applications of signal processing techniques are summarized in damage identification of various structures.

d. The advantages and disadvantages of signal processing techniques are reviewed.

Tran-Ngoc, H., Khatir, S., Ho-Khac, H., De Roeck, G., Bui-Tien, T. and Wahab, M.A.[34] the propose an efficient Artificial Neural Network (ANN) based on the global search capacity of evolutionary algorithms (EAs) to identify damages in laminated composite structures. With remarkable advances, ANN has taken off over the last decades ANN also has major drawbacks relating to local minima issues because it applies back propagation algorithms based on gradient descent (GD) techniques. This can leads to a substantial reduction in the effectiveness and accuracy of ANN. The researchers have been come up with some solutions to tackle the local minimal problems of ANN by looking for starting beneficial points to eliminate initial local minima based on the global search capacity of stochastic algorithms. it is commonly acknowledged that those solutions are no longer useful or even counterproductive in some cases if the network contains too many local minima distributed deeply in the search space. Thus here proposed a novel approach applying the fast convergence speed of GD techniques of ANN and the global search capacity of EAs to train the network. The core idea is that EAs are employed to work parallel with ANN during the process of training the network. This guarantees that the network possibly determines the best solution fast and avoids getting stuck in local minima. To enhance the efficiency of the global search capacity, in this work, a hybrid metaheuristic optimization algorithm (HGACS) of EAs is also proposed, which possibly gains the advantages of both Genetic Algorithm (GA) and Cuckoo Search (CS). GA is applied to generate initial populations with the best quality derived from the ability of crossover and mutation operators, whereas CS with global search capacity is used to seek the best solution.,To deal with the large amount of data utilized to train the network, a vectorization technique is applied for the data of the objective function, which considerably decreases the computational cost. The obtained results prove that the proposed method is superior to traditional ANN, other hybrid-ANNs, and HGACS in terms of accuracy, and significantly reduces computational time compared with HGACS

An efficient ANN based on a hybrid metaheuristic optimization algorithm is proposed to identify damages in laminated composite structures. It is common ground that because of applying back propagation algorithms based on GD techniques to train the network, the network of ANN may get stuck in local minima. This may decrease the efficiency and accuracy of ANN. To transcend these limitations of ANN, an efficient ANN based on a hybrid metaheuristic optimization algorithm is proposed.

Nedelcu, Dorian, and Gilbert-Rainer Gillich. [35] Observing the occurrence of cracks in the early stage remains a challenge, as changes in the modal parameters produced by these cracks are small. This remark is also valid for deeper cracks because in most experiments it is possible to acquire short signals, which ensure a coarse frequency resolution. the accurate estimation of frequency by standard methods is impossible.the aim is to improve frequency readability, designed an algorithm that implemented in the PyFEST application, written in Python programming language. It allows a fast and accurate calculation of harmonic components of a signal. PyFEST is based on an original signal post-processing algorithm, which consists of overlapping spectra for the signal iteratively cropped. The different signal lengths ensure different positions of the spectral lines in the overlapped spectrum. Therefore, adding numerous spectral lines of different positions in the overlapped spectrum it obtain a dense spectrum with significantly increased frequency resolution. From this spectrum, selected the three magnitudes of the individual spectra found in the frequency range of interest. By interpolation, it attains the maximum that has usually an inter-line position representing the estimated frequency. To this frequency, we apply a correction term that is known a priori and so to improved the frequency estimation. To test the reliability of PyFEST, provide examples for signals generated with known frequencies that have one or more harmonic components. For signals containing one harmonic component the exact frequency was found, while for signals with multiple components the error are less than 0.1%. The frequency change is exactly estimated for both types of signals. Because PyFEST allows observing minor frequency changes, so able to succeed to localize the crack position and severity in real beams with high precision.

PyFEST [36]

Feast (**Fea**ture **St**ore) is an open source feature store for machine learning. Feast is the fastest path to manage existing infrastructure to productionize analytic data for model training and online inference.

Feast allows ML platform teams to:

- Make features consistently available for training and serving by managing an *offline store* (to process historical data for scale-out batch scoring or model training), a low-latency *online store* (to power real-time prediction), and a battle-tested *feature server* (to serve pre-computed features online).

- Avoid data leakage by generating point-in-time correct feature sets so data scientists can focus on feature engineering rather than debugging error-prone dataset joining logic. This ensure that future feature values do not leak to models during training.
- Decouple ML from data infrastructure by providing a single data access layer that abstracts feature storage from feature retrieval, ensuring models remain portable as you move from training models to serving models, from batch models to real time models, and from one data infra system to another.

Toh, Gyungmin, and Junhong Park[37] the rapid progress in the deep learning technology, it is being used for vibration-based structural health monitoring. When the vibration is used for extracting features for system diagnosis, it is important to correlate the measured signal to the current status of the structure. The measured vibration responses show large deviation in spectral and transient characteristics for systems to be monitored. Consequently, the diagnosis using vibration requires complete understanding of the extracted features to discard the influence of surrounding environments or unnecessary variations. The deep-learning-based algorithms are expected to find increasing application in these complex problems due to their flexibility and robustness. This review provides a summary of studies applying machine learning algorithms for fault monitoring. The vibration factors were used to categorize the studies. A brief interpretation of deep neural networks is provided to guide further applications in the structural vibration analysis.

Power sources are important devices that need maintenance requirements to be estimated. Vibration occurs because of magnetic fields generated during power conversion. Harmonic vibration occurs without an external excitation device. The vibration characteristics depend on the efficiency of the power conversion. The rotation of elements also generates harmonic vibrations without excitation devices. Because rotating components have a strong influence on the vibration characteristics, the resulting signal processing needs to consider relevant variations.

The ambient excitation has been used to monitor large structures. Structural vibration is induced by variations in the surrounding environment (e.g., running vehicles, wind and interaction with nearby structures). The calculation of the vibration response requires transient vibration energy transfers to be considered. In addition, the vibration characteristics of the surrounding environment should be understood and correlated with the monitored structure. Excitation occurs throughout the frequency band when the system is excited by external forces amplified by an impact or random signal. The excitation can be performed at a predetermined frequency to observe the behavior in a specific mode. This direct excitation provides an advantage in terms of the interpretation of results and assumptions for the desired mechanical deformations.

summarizes the research using deep learning for structural health monitoring that were referenced in this review. A combination of various signal preprocessing methods and deep learning architectures is being studied for vibration-based monitoring. Structural health monitoring using vibration response has the elements necessary for classification by deep learning, such as a clear distinction between normal and abnormal status. Data processing can be used for data augmentation. In addition to ongoing developments in researches of deep learning, various and effective condition diagnostics are expected to be proposed. presented a damage indicator based on normalized modal strain energy indicator (nMSEDI) and compared the performance of the local frequencies change ratio (LFCR). Computational (CPU) time of LFCR based on FEM was about 60 s and nMSEDI took about 0.28 s. Wu et al.used 1-D CNN + SVM method with 358 samples per second processing speed. Inverse analysis has the advantage of short computation time because the amount of data calculation is smaller than that of deep learning. However, deep learning has the advantage of being able to perform health monitoring on complex structures with high accuracy.

Advances in machine learning technology have rapidly increased its application in vibration-based structural health monitoring, as summarized in this review. Since AlexNet's success in 2012, interest in deep learning has been increasing rapidly. Based on this trend, research on the possibility of applying deep learning to structural health monitoring has also increased. A database search showed that the number of works reported in the area of structural health monitoring with deep learning has been increasing each year from 279 in 2012 to 323, 402, 440, 433, 524 and 661 in 2013–2018, respectively. A further increase is expected in 2019. The use of structural vibrations for fault diagnosis is advantageous for intrinsic diagnosis of the installation responses. For practical applications, issues related to nonlinearity, nonstationarity and time variation should be resolved. Deep-learning-based algorithms commonly utilize big data. Consequently, they are advantageous in terms of robustness. The amount of data used for discrimination is large to filter out unnecessary information. However, it is important to ensure converged results and to overcome the problem of an aperiodic abnormality signal being generated. Studies are actively ongoing to use data augmentation or directly applying vibration to a system to detect an abnormal signal. The vibration responses are obtained in the time domain. The raw data were used for categorization and feature extraction. Signal processing (e.g., Fourier transform, Hilbert transform and wavelet transform) was also used. Deep learning is a multilayered neural network that can be fabricated in various ways, depending on how the layer is constructed. The deep learning algorithms established their own features that characterize the subject. Production of high-accuracy results is expected in a fast and efficient manner. Therefore, the use of deep learning to analyze unstructured data such as voice, video, photo and sensor measurements is increasing. Data labeling is not required for unsupervised learning. Data labeling requires a lot of time and effort in specific applications. Deep learning is expected to be a tool for solving complicated vibration problems and contributing to efficient structural health monitoring. This summary is intended to be used in future studies as a possible guideline when newly emerged machine learning algorithms are used for vibration-based structural integrity monitoring.

Rahul Semil, Pratesh Jaiswal[38] Moving component bearing is utilized to convey radial load and axial load or both just as. REB has nonlinear conduct make issue misalignment, surface waviness, fault happen at the inward race, external race, enclosure, ball or roller, so REB has a restricted life. Our concentration to evacuate fault diagnosis of bearing at the outer race has been investigating. For this purpose, REB vibration analysis is used. This paper present a support vector machine algorithm (SVM) approach with GA (Genetic algorithm) based optimization compare the result with SVM with cross-validation (CV) method along these lines, the information is processed correctly and an exact way. Time-domain Analysis, high pass and low pass filtering etc. used for feature extraction from vibration signal. Further, these feature extraction used as input to the SVM classifier. Support vector machine, a training given projected preparing information, the procedure yield perfect hyperplane. Feature extraction help to provides the actual condition of bearing. different signal processing techniques and process are used for fault diagnosis of bearing.

Mohd Ghazali, M. H., Rahiman[39], Unexpected machinery breakdown will incur significant losses, especially to the manufacturing company as it affects the production rates. During operation, machines generate vibrations and there are unwanted vibrations that will disrupt the machine system, which results in faults such as imbalance, wear, and misalignment. Thus, vibration analysis has become an effective method to monitor the health and performance of the machine. The vibration signatures of the machines contain important information regarding the machine condition such as the source of failure and its severity. Operators are also provided with an early warning for scheduled maintenance. Numerous approaches for analyzing the vibration data of machinery have been proposed over the years, and each approach has its characteristics, advantages, and disadvantages. This manuscript presents a systematic review of up-to-date vibration analysis for machine monitoring and diagnosis. It involves data acquisition (instrument applied such as analyzer and sensors), feature extraction, and fault recognition techniques using artificial intelligence (AI). Several research questions (RQs) are aimed to be answered in this manuscript. A combination of time domain statistical features and deep learning approaches is expected to be widely applied in the future, where fault features can be automatically extracted from the raw vibration signals. The presence of various sensors and communication devices in the emerging smart machines will present a new and huge challenge in vibration monitoring and diagnosing. Vibration analysis for machine monitoring and diagnosis has become cheaper and cheaper thanks to the emerging technology and development in the data acquisition process and signal processing techniques including the instrument applied. Nowadays, even inexperienced users can conduct effective vibration monitoring without the presence of an expert. In this study, we have conduct a systematic review of vibration analysis for machine monitoring and diagnosis, which can be divided into data acquisition, feature extraction, and fault recognition stages. Several RQs have been answered in this study which might provide useful information on this area. From the study, several key factors are determined:(i)With the advancement of powerful software and the Internet, a computer-based analyzer is preferable in the future due to its low cost and performance, which is as good as the standalone analyzer.(ii)Noncontact sensor is the future of vibration analysis for machine monitoring and diagnosis due to its flexibility and independence of any mass-loading effects, without compromising the signal quality.(iii)Time and frequency domain methods are suitable for stationary signals and time-frequency domain techniques are preferable for nonstationary signals and early fault detection.(iv)Deep learning, especially the deep transfer learning method, is starting to be applied in vibration analysis for machine monitoring and diagnosis as it helps in minimizing the requirement for expert knowledge in the complicated feature extraction step. Traditional AI methods such as SVM, NN, and fuzzy logic still require expert knowledge in the feature extraction stage of newly fed datasets.(v)Traditional time domain features such as RMS and crest factor are still relevant in the future and its application with AI will continue to increase.

Ramachandran[40] the use of machine learning methods for gear box vibration analysis for condition monitoring. Condition monitoring is already much practiced in many of todayand#8223;s engine rooms and plants, either by skilled engineers or diagnostic expert systems. However, techniques that rely on automatic pattern recognition have only recently been introduced into this field. Pattern recognition is a research area with a long-standing history, traditionally focused on finding optimal decision functions for static well-sampled classes of data. Besides issues encountered in any pattern recognition problem (feature extraction, small sample sizes, generalization), we face some special issues in condition monitoring of rotating equipment. This requires the use of (relatively novel) methods for blind source separation, novelty detection and dynamic pattern recognition. The knowledge of the condition of a machine may be obtained by selecting a suitable index and monitoring its value at regular intervals. With measured data (signal) one can do trend monitoring, condition checking and fault diagnosis. Fault diagnosis of bevel gear box using vibration signals was taken up for detailed study and forms the main theme of this research work. Fault diagnosis includes the methods such as shock pulse method; wear debris analysis, sound and acoustics emission and vibration analysis. Again each method has its own area of applications with pros and cons. Amongst these conventional techniques, fast Fourier transform (FFT) stands out and is widely used in industries. Characteristic frequencies are used as basis for FFT based techniques; characteristic frequency is a function of the speed of the shaft. Further, there are several other factors that interfere with the vibration signals. FFT based techniques are sensitive to such noises. Clearly, there is a need for an automated fault diagnosis technique with fault tolerance capability. Machine learning techniques seemed to be a candidate fulfilling these requirements. The machine learning approach to fault diagnosis of gear box using its vibration signals is taken up for study. There are three important phases in machine learning: Features extraction, Feature selection and classification. There are several features that describe the condition of the gear box under investigation. In the present study the following features were used: • Statistical Features • Histogram Features • Continuous Wavelet Features • Discrete Wavelet Features Decision tree ID3 algorithm was used for feature selection and robust four features were selected. If more than four features appear in the decision tree, four features that appear on top of the decision tree were selected. If the number of features that appear on the decision tree was less than four, then all appeared features were selected. With the selected features, the classification was performed with the following classifiers: • Artificial Neural Networks • ID3 Algorithm • Fuzzy Inference Engine • Support Vector Machines • Proximal Support Vector Machines .

Chapter 3

Research Gaps & Proposed System

3.1 Research Gaps

3.1.1 Technological drawbacks

The Vibrations analysis are impactfull only when the implemetation and algorithms applied should be very accurate and able to perdict or analysis the data and vibration , drawback comes in understanding because the algorithms are applied to perform a specific task for a fixed outcome but are not capable of doing so the backfalls occurs when there is a lack of preprocessing or knowledge before implemtation of the algorithms.

From the literature survey it is found that there are challenges in data collection using vibrometer and furthermore it is more difficult to predict the strength of the structures due to non-automated system of detection. Domain of automating vibrometer is very naïve and very less or no work is being found in the literature.

FFT and SVM are two major technology taken from the wide range of machine learning because as per the scenario of automation or formation of the real time values the data transformation into different domain is required , the other is with the type or historical data analysis . The FFT algorithm is known to convert and predict result from time domain to the frequency domain but the major issue is how , the plotting and transformation is done in MATLAB environment and the MATLAB is paid it is not open source environment and the working is kind of complex as compared to that of other open source programming language

MATLAB is two major disadvantage of MATLAB programming language:, the **Interpreted language and Cost**

The first disadvantage is that it is an interpreted language and, therefore, may execute more slowly than compiled language. This problem can be check by properly structuring the MATLAB program.

A full copy of MATLAB is five to ten times more costly than a conventional C or FORTRAN compiler. This comparatively high cost is more than offset by the decreased time necessary for an engineer or scientist to create a working program, so MATLAB is cost-effective for businesses. However, it is too expensive for most individuals to consider purchasing. Fortunately, there is also an inexpensive Student Edition of MATLAB, which is an excellent tool for students wishing to learn the language. The Student Edition of MATLAB is virtually identical to the full edition.

FFT is used for domain transformation is known but how to perform with is the alternative of FFT is not certainly mentioned , because knowing every language is difficult , and for students of other domain must be certainly not knowing the math or the formula behind the implementation pf the algorithm .Rather than using the MATLAB python is a great option for FFT is able to apply the mathematics behind the algorithms just by importing the libraries , available inbuild in python packages . it also able to visual the waves into various different plots and graphs because of its visualization library matplotlib , it is an amazing library to plot different types of graphs and plots .

FFT in python becomes more handy due the reason of complex coding in MATLAB .

SVM is the support vector machine is the machine learning algorithm used for non linear supervised learning classification , the implementation of SVM is pretty simple when dealing with a non linear data set .

The Non-Linear data under the Supervised learning where the data does not follow any particular trend thus the use of classification algorithm of Supervised learning i.e is SVM , Support Vector Machine is best suitable with the data set used , the SVM will able to predict the accurate result of the dataset .

The SVM works well when the data selected is trained properly , the problem arises with testing data or the real time data set where the SVM faces some drawbacks ,

1. SVM algorithm is not suitable for large data sets.

2. SVM does not perform very well when the data set has more noise i.e. target classes are overlapping.

3. In cases where the number of features for each data point exceeds the number of training data samples, the SVM will underperform.

4 As the support vector classifier works by putting data points, above and below the classifying hyperplane there is no probabilistic explanation for the classification.

The conversion of the beam reading, Shape boundary reading should also be done so the analysis and unit reading will become more understandable and the outcome will become more efficient after we convert these readings .

If the dataset belong to the category , like images , the deep learning and neural networks combined with Open cv and image processing methods of AI to included for performance measurement and predicting the result , CNN is the best suitable for image data , CNN is Convolution Neural Networks.

The CNN is generally required when the dataset or the real time implementation is images ,CNN is able to predict the result directly through images , but in case of nonlinear data CNN fails as it is unable to find out the treand or similarity in the numerical data as the data is not stable it is non linear beam data set .

The CNN is applied with the known theory of neural networks with is not easy it is a complex technique and method is thus not suitable for numerical data implementation also neural network computational model uses a variation of multilayer perceptrons and contains one or more convolutional layers that can be either entirely connected or pooled.

- CNN do not encode the position and orientation of object.
- Lack of ability to be spatially invariant to the input data.
- Lots of training data is required.

CNN and SVM together able to form or produce good outcomes but the problem is the related dataset the dataset of images of very large size which require huge memory storage , which is costly and expensive , for working students the configuration of system cannot handle such data .

And reading with non linear data must not also be used for analysis directly before preprocessing .

3.1.2 The Data Set and Real time input

The dataset is consisting of reading of the Cantilever Beam via a sensor called Vibrometer .The issue with the dataset is the non linear data set which is no trend to predict or to apply the suitable machine learning algorithm ,the values are so discrete finding spread or normalization is also an hard task , ahead is the if the dataset from time domain is transformed into frequency domain still the values are oscillating and thus there is no specific fit for the dataset many different algorithm need to be checked and the algortim with accurate result is selected . SVM in this case is accurate .

Before even applying the algorithm for machine learning the prepocessing is must to make the data noice free and no other errors regrading the data shape ,size , values etc occurs .

3.2 Proposed System

The Vibrometer automation system is the model which is interrelated between two major and different fields then machinal and computer science . The Vibrometer or Vibration analysis for Structural Health Monitoring is a concept of physical and physics and on the other hand the check is to be done through the predictions from the machine learning model and outcomes values is from the computer science .

Designing this system for SHM using machine learning with the help of vibrometer through the beam of Cantilever.

Domain of automating vibrometer is very naïve and very less or no work is being found in the literature. This work hence proposes a system based on Machine learning techniques that will take the input from the vibrometer reading as shown in fig 1 .

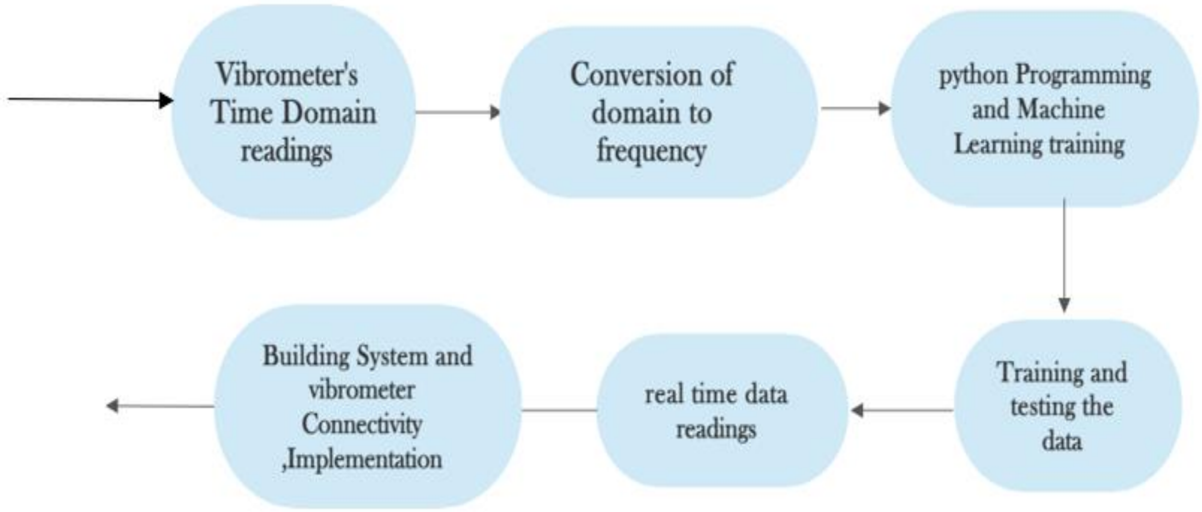

Fig 09 Flow-Chart : Working Flow of the proposed System The working flow and the step by step assumed system is represented in this flowchart

Source	CH1
Second	Volt
-0.8192	-9.8
-0.81912	-9.8
-0.81904	-9.8
-0.81896	-9.8
-0.81888	-9.8
-0.8188	-9.8
-0.81872	-9.8
-0.81864	-9.8
-0.81856	-9.8
-0.81848	-9.8
-0.8184	-9.8
-0.81832	-9.8
-0.81824	-9.8
-0.81816	-9.8
-0.81808	-9.8
-0.818	-9.8
-0.81792	-9.8
-0.81784	-9.8
-0.81776	-9.8

Fig 10 Original Dataset in Time Domain

The exact reading in seconds and volts, these reading are obtained through the cantilever Beam , through Vibrometer acting as a sensor .

This work proposes a machine learning model that will be trained and tested for the captured data. The goal here is to make the system real time by converting the reading of the vibrometer into visual wave to be able to predict the value to keep a check on the strength. Once the model is built on the dataset then the aim is to use the real or random values and check that the outcome is accurately fits or is able to provide the solution. The machine learning algorithms like Linear regression , SVM that have worked on the similar kind of vibration data is been taken in consideration.

The objective of the work is designing an automatic vibration detection system that is capable of doing

1. the data set analysis
2. machine learning model check
3. transformation of the data values into amplitude and frequency.
4. the method of FFT fast Fourier Transform for discrete data.

The initial phase of the model is implemented and can be verified by visiting the Kaggle https://www.kaggle.com/datasets/lalisharma/vibrometerdataset?select=data+ml.csv [9]

The goal here is to make the system real time by converting the reading of the vibrometer into visual wave to able to predict the value or to keep a check . Once the model is build on the dataset then the aim is to use the real or random values and check that the outcome is accurately fits or is able to provide the solution. This work proposes a real time implementation of Structure strength prediction using machine learning techniques.

. the methods are very much simple it the use of machine learning algorithms , time data , multi dimension linear regression algorithms .

Moving ahead as if possible to design in the future the actual proposed model will include the the fault recognization .

Fault Recognization in this system is also our future scope . is the SHM , it is what is the state of the structure before and after certain range of vibration .

The changes in vibration signals due to fault can be detected by employing signal processing methods. It can be used to evaluate the health status of the machinery. The nature and severity of the problem can be determined by analysing the vibration signal and hence the failure can be predicted.

Certain Data science methods are the actual flow of data to find the proper and correct system .

1 Data Acquisiton

Analyzer

Sensor

2 Feature Extraction / Signal processing

Time Domain

Frequency Domain

Time Frequency Domain

3 Fault Regonisation / Automation (SHM)

AI Based

Machine learning predictions

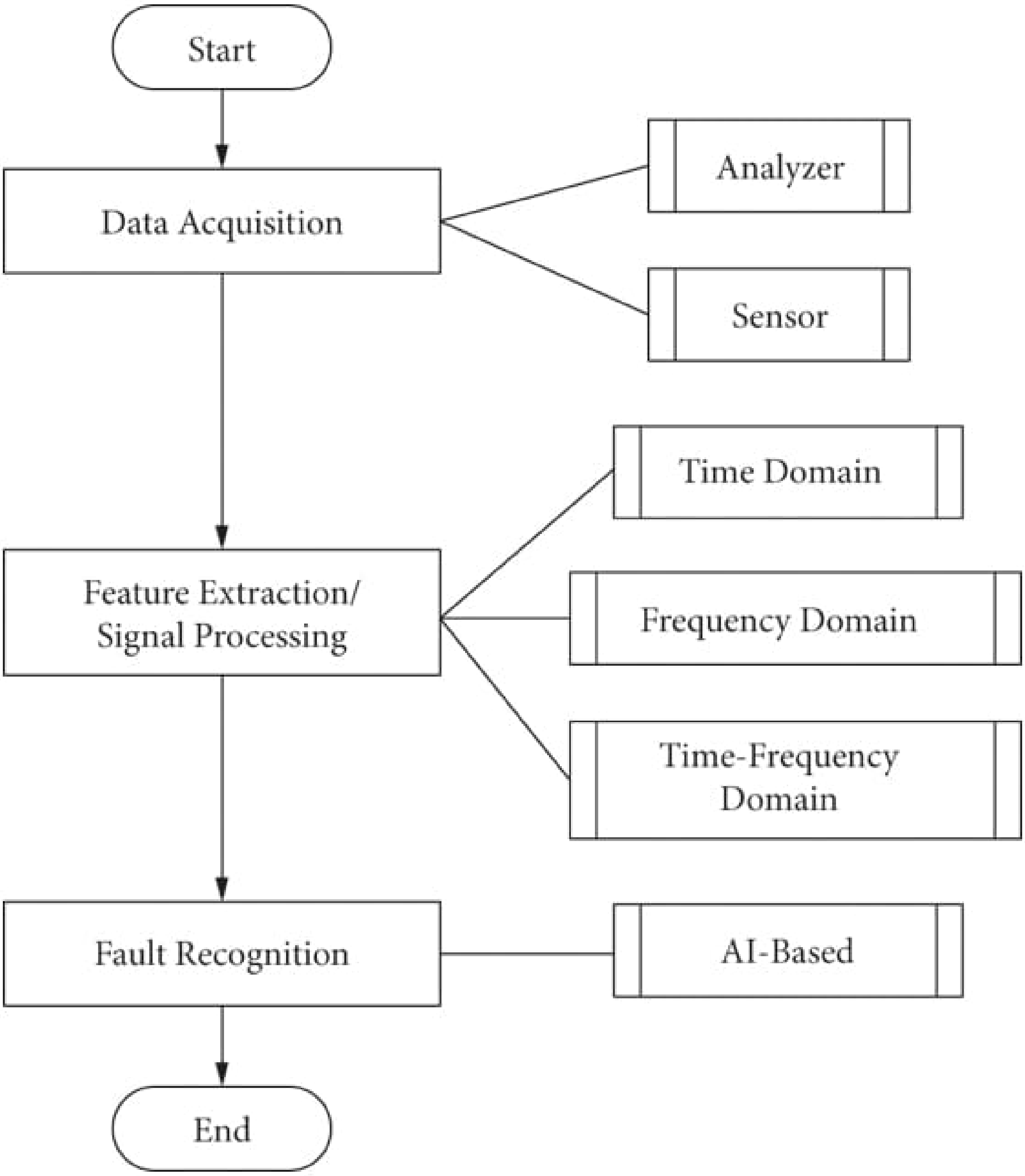

Fig 11 : Expected Data flow

Chapter 4

Results and discussions

4.1 Result

The original dataset is converted and the pre-processing has been applied the information is also attached here [41]. The python version here used is python 3.9[42] , the practical or model building is done on the Vibrometer dataset project on Kaggle form account [41]. It is a Notebook platform where all the performance and working and progress is available real time , and contribution is also required .

The Result 1 was by the conversion of domain also through the tool and the FFT algorithm in the Frequency domain from original time domain . The vibrometer reading frequency and amplitude the maximum frequency is the amplitude .

Where the seconds in time to frequency in hertz . this was the first step where the domain conversion is the task and the outcome is in frequency domain .

```
     -1.220703125  -4.9
0       -1.228220  -4.9
1       -1.229000  -4.9
2       -1.221060  -4.9
3       -1.221180  -4.9
4       -1.221299  -4.9
..            ...   ...
144     -1.238236   5.0
145     -1.238359   5.0
146     -1.238482   4.9
147           NaN   NaN
148           NaN   NaN

[149 rows x 2 columns]
     -1.220703125  -4.9
0       -1.228220  -4.9
1       -1.229000  -4.9
2       -1.221060  -4.9
3       -1.221180  -4.9
4       -1.221299  -4.9
..            ...   ...
142     -1.237991   5.0
143     -1.238114   4.9
144     -1.238236   5.0
145     -1.238359   5.0
146     -1.238482   4.9

[147 rows x 2 columns]
```

Fig 12 - Result 1 : The frequency domain reading after FFT and tool conversion .
The total number of observations are 147 rows and 2 columns

Result 2 The dataset is divided into two parts where major is the training part and the remaining is the testing , this figure is the algorithm and to find the discreate values in data also the spread or normalization of the data is represented .
The data is divided into training and testing so to work on it individually
the training and testing important because the machine learning is self learner once trained correctly , to find the accurate results , testing is to check the working on new data values .

```
[[-1.222015   ]
 [-1.2367665 ]
 [-1.233714  ]
 [-1.227898  ]
 [-1.23408   ]
 [-1.22813   ]
 [-1.229588  ]
 [-1.23566627]
 [-1.237501  ]
 [-1.234567  ]
 [-1.232498  ]
 [-1.232134  ]
 [-1.228018  ]
 [-1.224409  ]
 [-1.227536  ]
 [-1.231041  ]
 [-1.236521  ]
 [-1.2359106 ]
 [-1.235177  ]
 [-1.2318911 ]
 [-1.23481181]
 [-1.22657   ]
 [-1.237868  ]
 [-1.232863  ]
 [-1.222374  ]
 [-1.22874275]
 [-1.2328996 ]
 [-1.2311632 ]
 [-1.236155  ]
 [-1.2226134 ]
```

Fig 13- Result 2: Data training

```
 [-1.226452  ]]
[-1.221657  -1.22369   -1.22405   -1.235299  -1.238114  -1.226933
 -1.22597   -1.22345   -1.234324  -1.22393   -1.2256103 -1.230193
 -1.2366442 -1.22825   -1.229211  -1.231769  -1.222733  -1.227295
 -1.23262   -1.2217769 -1.231527  -1.225249  -1.238359  -1.23092
 -1.2350558 -1.22476   -1.238236  -1.23164   -1.230799  -1.2334714
 -1.229951  -1.222972  -1.226211  -1.226813  -1.226091  -1.22106
 -1.22838   ]
```

Fig 14- Result 2 : Data testing

Result 3 SVM The supervised Classification algorithm used for the non linear kind of data , generally provides the support boundary depending on the type of data set its deal with .

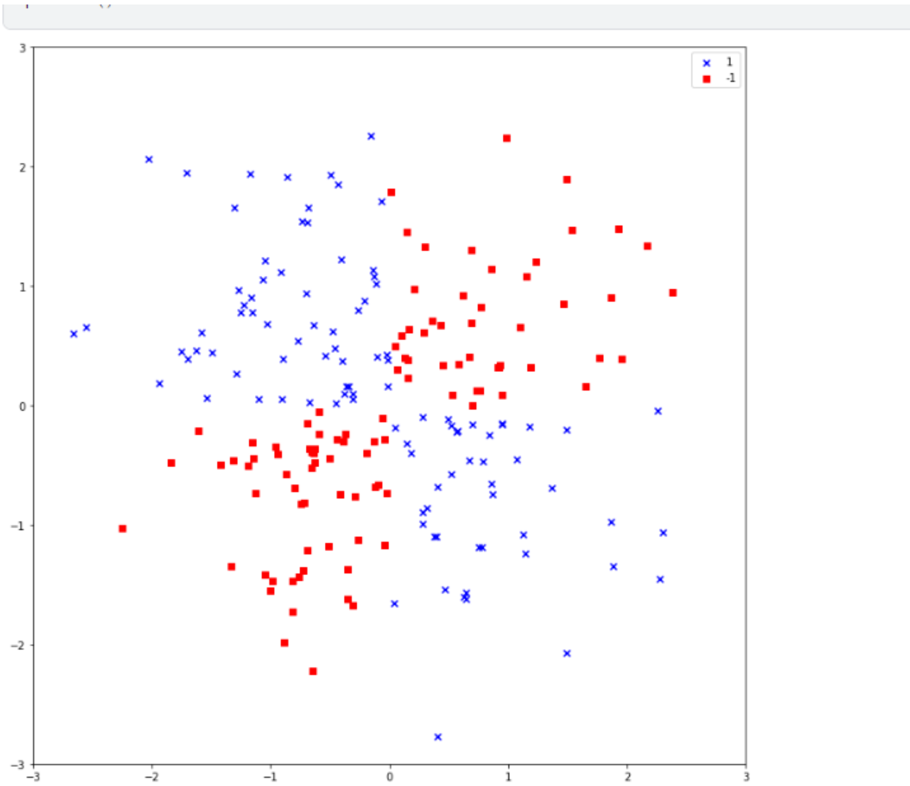

Fig **15-** Result 3**:** Discrete Value Dataset representation the normal spread and SVM results

SVM modelling is not able to predict the correct and accurate result with an accuracy of nearly 57.67%

SVM The supervised Classification algorithm used for the non linear kind of data , generally provides the support boundary depending on the type of data set its deal with .

Though this algorithm the discrete Fourier in the dataset is being identified this the first algorithm to be worked on. it will return the coefficients A, B etc corresponding to some fixed frequencies.

The methods fits the model and the real time data also fits the model we will able to see the working hardware called vibri (vibrometer laser system) converting and detecting the age, quality , vibration of the object or surface through the device which has the machine learning training and the real time data as the testing part **.**

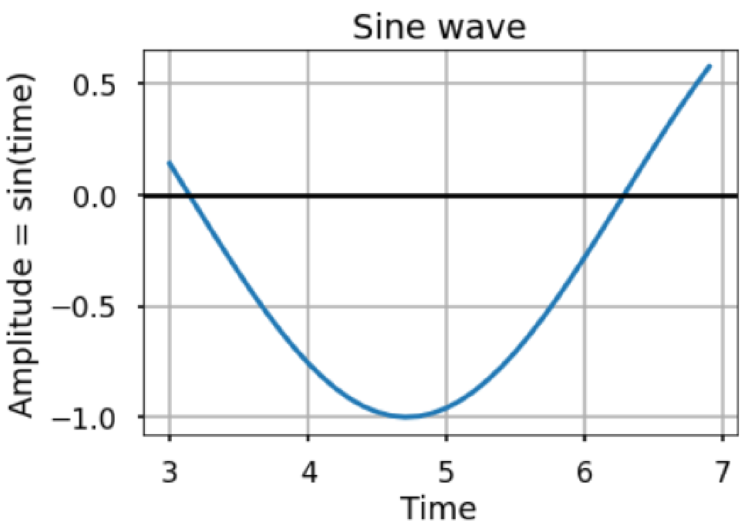

Fig 16 - Result 4a : Sine Wave plot from the time and amplitude

The plot is between the x and y axis with x label –time and y label – Amplitude

Amplitude = np.sin(time)

Where np is numpy library of python

And sin is the angel

The values of time and Amplitude are taken in a real time input as variable a, b also included

For all the different value in the real the result ia also differing as the oscillation of values .

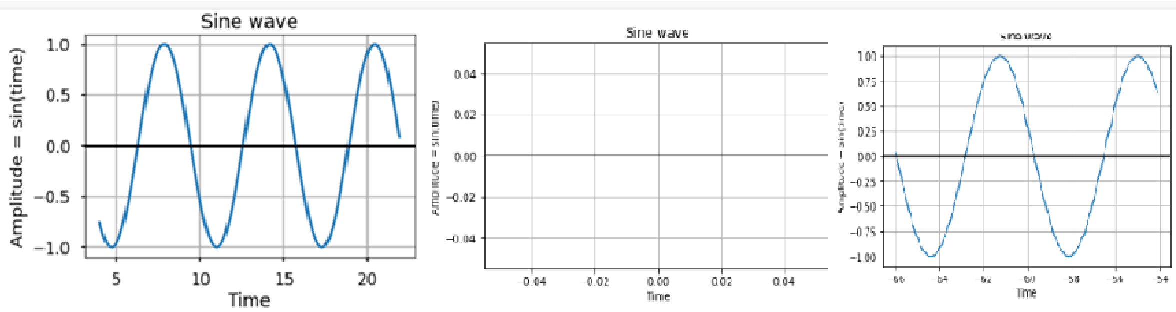

Fig 17 - Result 4 b: Sine Wave plot from the time and amplitude for different values of x and y respectively

The learning is the result differ according the values entered , the graph is also constant when both the values are equal .

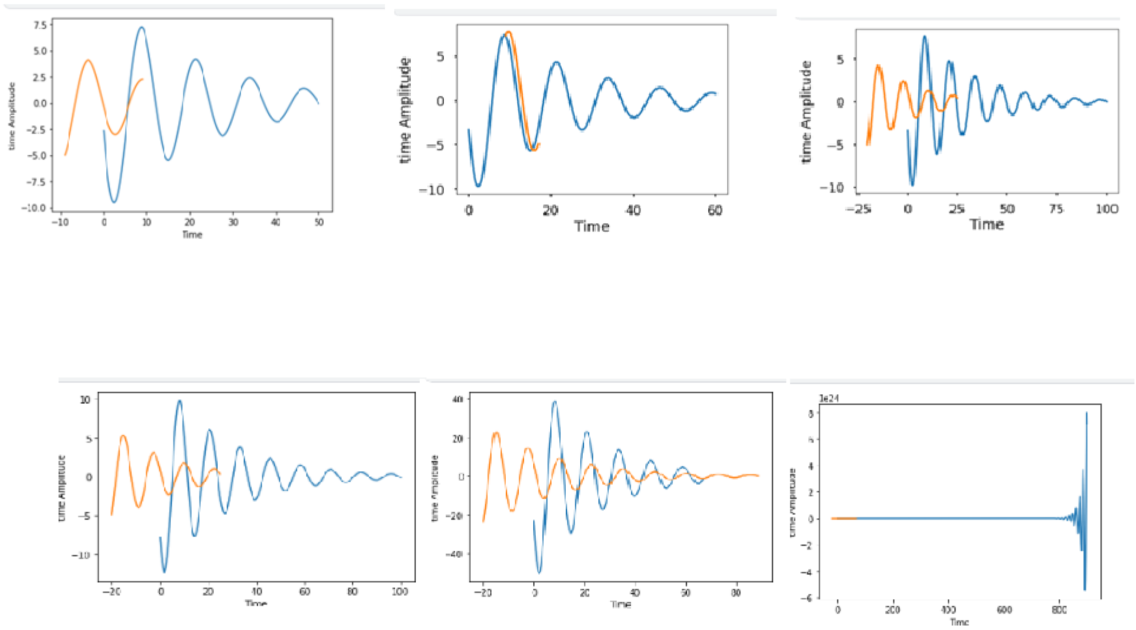

Fig 18 - Result 5

The real time oscillation though input ranges from the dataset reading , the matlplotlib is a visualization library , which is able to produce the time and time Amplitude .

The oscillation from -5 ,5 (the reading oftime and Amplitude) The plotting result is able to produce between the time and Amplitude . For Different reading the oscillations differ .

.

Expected outcomes in both the domain of time and frequency domain should look like this

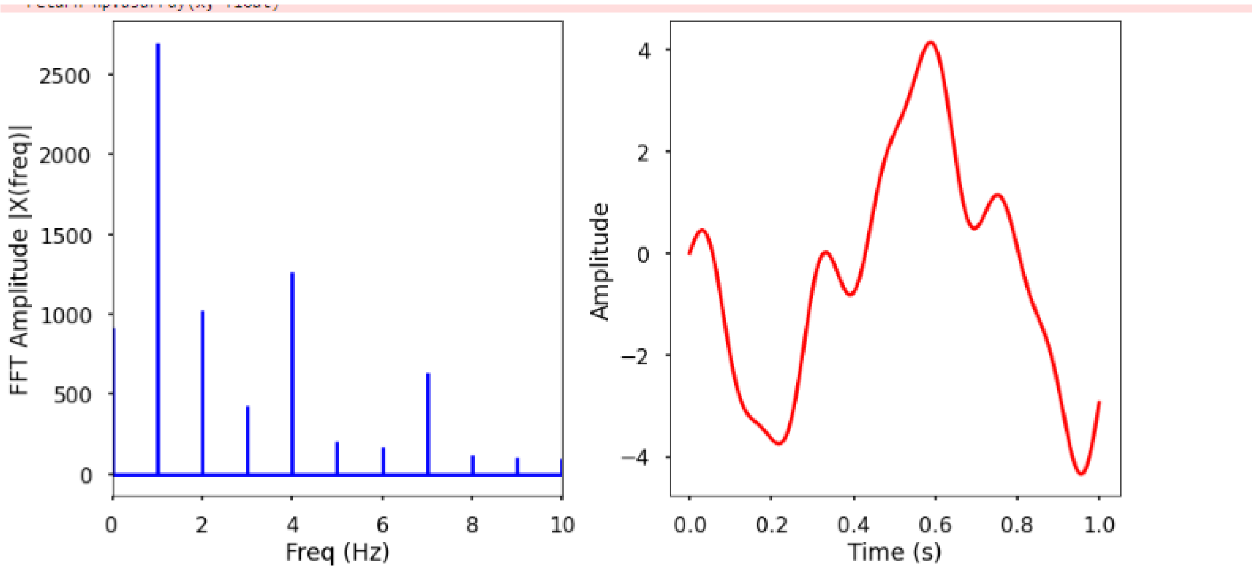

Fig 19 – Result 6: Expected is to check the view of result must be in these form

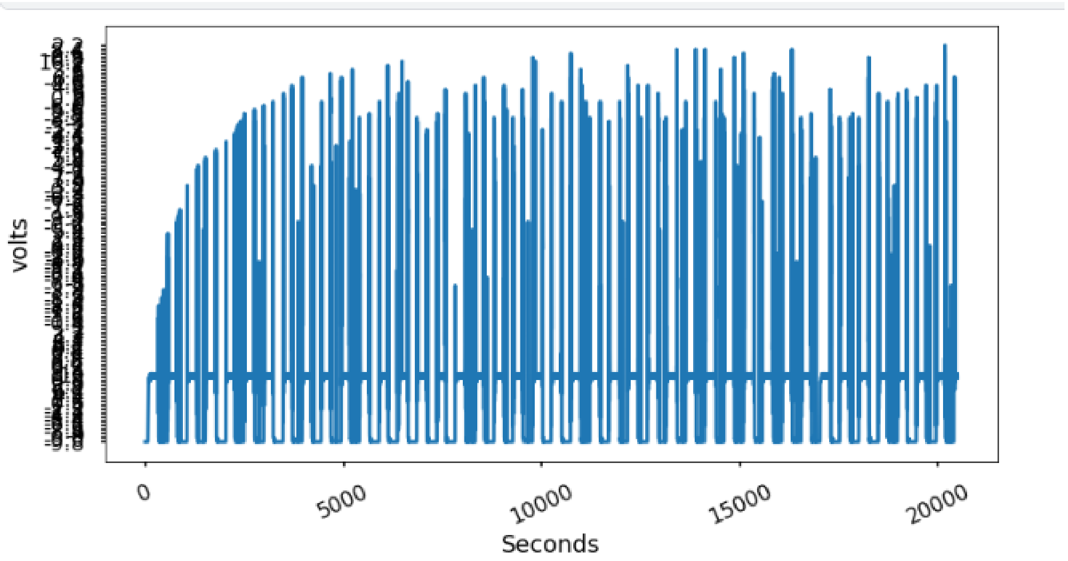

Fig 20 - result 7: this for time and volts i.e seconds and volt

The original data set and the refence from the MATLAB result are certainly not exact as the actual outcome the difference is in the outcome along the FFT algorithm but some how due to error in the maybe training of the data using SVM it is not able to predict the precise result comparing with the actual outcome

Similarly as there is not the accurate result in the time similarly there is also issue with the frequency domain the result is precise but not accurate .

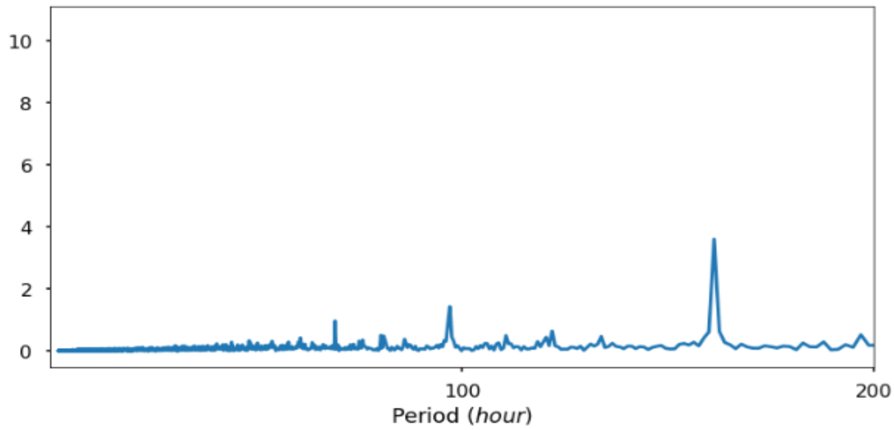

Fig 21- Result 7: the plot between the frequency domain

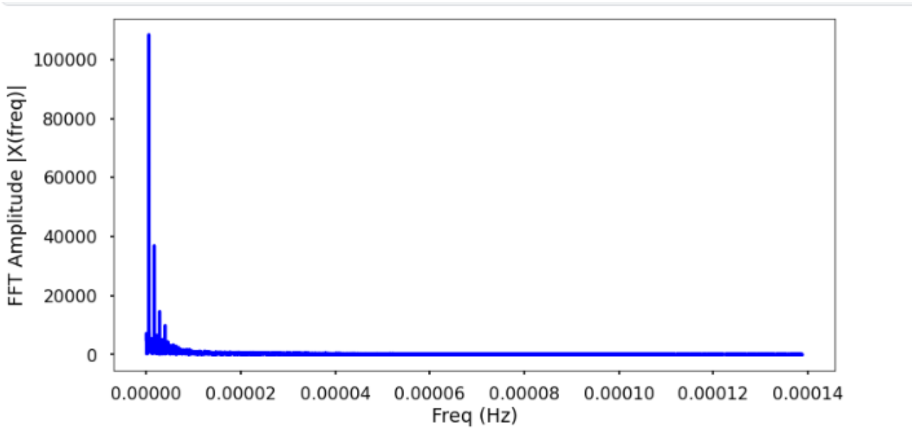

Fig 22- result 7

the frequency domain graph plot but the result doesn't match as the model is not able to predict the exact out of it as the training and testing of the data set.

4.2 Discussions

The results obtained through all the steps of data preprocessing and the machine learning is the very initial and moreover important for this whole system . The data is the most important and way effective part in any model , project to able to work properly . if the there is any minor lack in the dataset at the time of data acquisition and pre-processing .The project was kind a tough task as there were certain barriers link lack of resources ,lack of domain knowledge , lack of clever thinking for optimization , but as the work flow moved ahead the path became more and more clear and goal seems less difficult .

The ultimate goal and the idea behind taking this project and able to work on is itself a very efficient and knowledge boosting . the learning from each step until the ultimate goal .

Though still there are few more step required to achieve the ultimate goal but the confidence of able to do it in the coming future is what keeps motivated .

FFT results an algorithm that computes the discrete Fourier transform. It quickly computes the Fourier transformations by factoring the DFT matrix into a product of factors. The results mentioned above are all obtained by directly applying the algorithm on the data set of time domain .

The FFT works very well in the python environment but due the pre issues like training and testing lack the expected result through SVM is not able to be predicted still the FFT worked as the main driving algorithm in this model .

The SVM is the only suitable algorithm under the supervised learning machine learning because it predicts data over boundaries and also able to work with the non linear data set with very helpful . If the data set must be linear it will be easily predictable but the data set is non linear . this lead to the decrease in the accuracy . .

The SVM was able to only give 57.67% of the expected accuracy with is not but not acceptable also . Because the system is made with this accuracy will not be able to give the good or right alert for the SHM ..

The much further idea is to just make a system which is able to give the each second reading and graph analysis so that the health monitoring of structure can be kept in check .

Chapter 5

Conclusions and future work

5.1 Conclusions

5.1.1 Limitaions :

The working flow of the model and the results are obsereved and concludes that the vibrations are the singls rechived from any source to a structure , the frequency and amplitude of the these beam singnals can somehow able to damage the structure . and the structure receives or get hit by these waves of signal regualary and every time the may be certain damage . when the any platfdorm like road bridge or loading bridge , train bridge , railway tracks , huge buildings consturctuins get hit by these vibrations of any frequency and amplitude which keeps on depleting them slowly , but evry building or pathform have certain maixmum value or capacity that after which the quality of the plaotform is destroyed In this case the system is very helpful . the autmaticreading are being checked and if there is vibration abov an exprected or fixed values the danger is real which can be predicted by the system expeted to be build in the future .

This will reduce the harzard to life and property . but the main problem still to overcome is accuracy of the system . in future if the model got build and came in the market retailded but still the reading and vibration result it is giving are not correct and accurate then this wil lead to a wrong information generation .

The model aims to provied the information of when the structure reuried renovation or the authorities orowner is aware aboult it or maybe not aware about it but the unaccurate model is nt able to give the correct result thus it will or may fail .

On the other hand the reailbity on the system will incerase and the author authorities orowner may become less concerned and here where there are chances of mis lead fault .and the deplection in the structure is not treated . thus it is requried for the owner to keep in check of the structual requriment .

Once the model is build on the dataset then the aim is to use the real or random values and check that the outcome is accurately fits or is able to provide the solution. This work proposes a real time implementation of Structure strength prediction using machine learning techniques.

The methods are very much simple it the use of machine learning algorithms , time data , multi dimension linear regression algorithms but these also are not help for 100% accuracy of the result.

But the result isn't the same as expected the problem is with the model implementation .also it depends on to reduce the complexity of the data set .

5.1.2 Recommendations

The complexity reduction is the grate solution to the problem of accuracy and to the algorithm where SVM is used as the base ,the reduced complexity will able give the more accuracy and model is then ready for work and future requirement achievement .

SVM The supervised Classification algorithm used for the non linear kind of data , generally provides the support boundary depending on the type of data set its deal with .

Though this algorithm the discrete Fourier in the dataset is being identified this the first algorithm to be worked on. it will return the coefficients A, B etc corresponding to some fixed frequencies.

The methods fits the model and the real time data also fits the model we will able to see the working hardware called vibri (vibrometer laser system) converting and detecting the age, quality , vibration of the object or surface through the device which has the machine learning training and the real time data as the testing part **.**

The dataset is consisting of reading of the Cantilever Beam via a sensor called Vibrometer .The issue with the dataset is the non linear data set which is no trend to predict or to apply the suitable machine learning algorithm ,the values are so discrete finding spread or normalization is also an hard task , ahead is the if the dataset from time domain is transformed into frequency domain still the values are oscillating and thus there is no specific fit for the dataset many different algorithm need to be checked and the algorithm with accurate result is selected . SVM in this case is accurate .

5.2 Future Work

The future scope of the proposed model can be used for detecting earthquake, the age or quality check of dams, bridges, railway lines etc . This will check and also inform about the natural disasters which will be a helpful and reduce of losses of life and property. It can also be used in medical field for finding the for human bone strength. It will also be helpful in various other fields yet to discovered. If in future the dataset is in form image , the image processing including the concept of deep learning and CNN can be used and implemented to get the results , the CNN will directly able to identify the strength of structure through images .

If the result are predicted to be very near to an accuracy of 85-90% then the working model which is the a vibration sensing device which is a sensor used made up of raspberry pi , this will be containing all the methods and taking the real time value of vibration and give the health check of the structure ..

Raspberry Pi to learn programming skills, build hardware projects, do home automation, implement Kubernetes clusters and Edge computing, and even use them in industrial applications. is a tiny computer about the size of a deck of cards. It uses what's called a system on a chip(Opens in a new window), which integrates the CPU and GPU in a single integrated circuit, with the RAM, USB ports, and other components soldered onto the board for an all-in-one package.

The reading through the vibrometer or other sensors are taken in the computer system which requires to have a database where all the real time are being stored in form of csv file and every the time the new values is being inserted the database the csv file gets updated with the new result and then the computer will give the result of values inserted in the data set . Once this is done other future step is make an fault detection system or alert system.

The alert system will automatable vibration-based Structural Health Monitoring (SHM) alert system. The proposed method consists in applying an Automated Frequency Domain Decomposition (AFDD) algorithm to obtain the eigenfrequencies and mode shapes in real time from acceleration measurements, allowing to provide a diagnosis based on a Support Vector Machine algorithm trained with a database of the modal properties in undamaged and damaged scenarios accounting for temperature variability. The result is an alert system for controlling the correct performance of the structure in real time with a simple but efficient approach. Once the alert is triggered, the undamaged mode shapes (which could be previously stored in a database of modal parameters classified by temperature) and the current (damaged) mode shapes, can provide guidance for further application of Finite Element Model Updating (FEMU) techniques. The method is trained and validated with simulations from a FE model that is calibrated employing a genetic algorithm with real data from a short-term vibration measurement .

This is not only able to work in SHM but will also be able to work in other sectors of human protection and walfare . the human disaster management , health check ,bone check , health sector ,electronic sector , automobile sector etc .

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