Non-Invasive Bone Disorder Detection Using KNN Algorithm

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Abstract—
Bone Disorder is one of the common abnormalities in the world which causes the bones in the body to get weakened or damaged due to internal factors such as genetic disorders, osteoporosis, etc., or external factors that include trauma or accidents. Imaging techniques such as X-ray and CT scans are used to detect bone disorders that may cause harm to the patient and hospital surroundings. The patients also should depend on the radiologists in these techniques. The proposed system is used to determine various parameters of the bone disorders in advance with the help of the sensors such piezoelectric, temperature and gyroscopic sensors embedded with a microcontroller. Pressure, temperature and angles of knee joint is measured for identifying the bone misalignment. The bone disorder dataset from Kaggle is collected. The 70% of dataset is used for training in KNN algorithm, then the 30% of the dataset is used for testing. The acquired parameters from the different sensors are sent to the cloud by Wi-Fi which is used to analyze bone disorder detection using KNN algorithm and the result will be displayed in the web application for giving alert message. The prediction accuracy of proposed system is evaluated and found to be 92%.

Keywords: *Bone Disorder, Machine Learning, KNN, Non-Invasive.*

I. INTRODUCTION

A bone issue, sometimes referred to as a skeletal ailment, is any illness that affects the normal structure and function of the bone. They can affect any part of the skeletal system, including the bones, joints, and connective tissues. It is a condition where the bones' strength or flexibility is affected. Bone disorders may arise as an output of a variety of parameters, including inheritance, trauma, infection, aging, hormonal imbalances, and lifestyle choices. Based on the kind and severity of the bone abnormality, the symptoms might vary and include pain, stiffness, edema, discomfort, loss of movement, and fractures. [11] Early detection of the condition and the use of the proper medical care are crucial for controlling bone pain. Several bone illnesses might either have no symptoms at all or have symptoms that vary depending on the circumstance. Since it typically goes undiagnosed until a bone is broken, osteoporosis, for example, is known as a "silent" condition. Osteomyelitis patients may experience edema, redness, and warmth at the infected area. Fatigue and weight loss are indicators of bone cancer, and a lump or a tumor may also be present. General signs of a bone problem include: weakness, joint pain, back pain, infections, fractures, sprains, and bone pain.

The knee is the area in human body that is most frequently damaged. The three main causes of knee joint injuries are trauma injuries, long-term cartilage deterioration (OA), and autoimmune illnesses (rheumatoid arthritis)—can be highly diverse in terms of nature.

II. LITRATURE SURVEY

Vibro-Arthographic signal detection - Bone disease is a common abnormality in vast amount of people. The modest stiffness gradually gives way to joint immobilization. X-rays are the common technique used to see the joint, while ultrasound and magnetic resonance rarely practiced. Both invasive and non-invasive procedures can be categorized. Imaging studies, which are frequently performed in an intrusive manner, don't reveal information regarding early problems in joints, it can also cause harm to the subjects. To non-invasively identify bone issues early. The VAG signals captured on the dubious bone joint surface are processed with LabVIEW software to provide specifics about the underlying bone issues. This can be broadened to include the early detection of bone problems.[1]

Worldwide, 200 million individuals are plagued by osteoporosis which is a serious bone metabolic condition. This study looked at how the performance of the antenna might be affected by the presence of a human body phantom close by [4]. Additionally, the relative absorption of the microwave signal as it travelled within bone with various mass in the density was measured using a pair of monopole antennas and vector network analyzer (VNA). Here, animal bones were employed as that sample, and to study impacts of skin, a skin phantom replica was invented.[2]

The age of the bone skeleton evaluation is a normal and a day-to-day clinical procedure is used to study endocrinology, and genetic and development abnormalities of infants and children. Unfortunately, clinical explanations and bone age assessments are very overdue method, worker intensive, and sometimes vulnerable to inter-observer variance [3]. This advocates require for a completely automatic system for bone age evaluation. To determine the pediatric bone age automatically from a hand radiograph, regression convolutional neural network (CNN) is used. This network was put under increased strain to draw attention to certain bone age-related areas in the X-ray images.[9] Specifically, in order to execute all of the images and to produce the coarse-fine concentration maps as input variables for the statistical network, the attention module was adopted first.[5]

Repetitive stress causes bone stress injuries (BSI), patterns of loading that don't provide bones enough time to heal. Infra-Red Registered Quantitative Ultrasound (IR-QUS) method, intended at assessing BSI (Blood Stream Injuries) on the premise of surface quality as a sign of rapid bone healing.[7] IR-QUS gathers angle-diverse data and acoustic data on a point of focus to identify the ratio of diffusive to specular scattering rises.[8] Illustration of the method's sensitivity to describe surface roughness on the capability of detecting a particle at a size of tens of microns. Circumscribed field of fractures on an ex vivo intact bone specimen. Preliminary findings point to a viable method for detecting rough ended surfaces with an increasing diffuse-to-specular energy metric 10 dB in comparison to smooth areas.[6]

III. METHODOLOGY

This Section presents important concepts for understanding the proposed approach. Subsection III-A has concepts of KNN.

A. KNN

The KNN which is a ML technique, places the observed values in the category that is most similar to the trained values on the assumption that the observed value is similar to the trained data set. The KNN algorithm stores all the information that is available and classifies the new input based on similarity.

Algorithm of KNN

Step1: K number of neighbor is selected
Step 2: Euclidean distance is calculated

$$Euclidean\ distance = \sqrt{(x2-x1) + (y2-y1)}$$

Step 3: Calculated Euclidean distance should be arranged in ascending order and K-Nearest Neighbor should be taken.
Step 4: For each class, the number of points in the data among these K nearest neighbor should be calculated.
Step 5: The modal file will be produced after new data points are added to the class where the n-neighbor count is higher

B. Proposed System

The proposed system incorporates microcontroller and various types of sensors to detect the vital parameters of patients. The bone disorder can be detected in advance with the help of ML algorithms. In order to measure their accuracy, sensitivity, and specificity, machine learning technique, KNN algorithms, is utilized.

Battery (Lithium ion) has 3.7 V which is connected to boost convertor, that converts the voltage of battery from 3.7 V to 5V because all other components used have 5V. Three different sensors like MPU-6050, DHT 11, Piezoelectric sensor are connected to Node MCU which are used to detect the angle of the bone, temperature, pressure respectively. The data collected from these are send to the cloud where machine learning is performed for the detection of bone disorder as it is illustrated in fig1 .

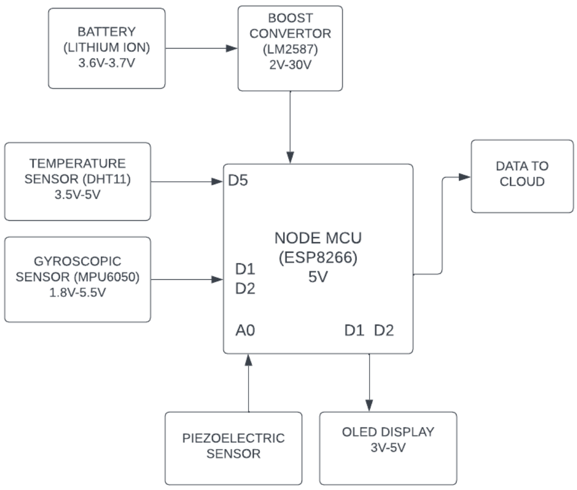

Fig 1.Proposed System Block Diagram–Hardware

C. Hardware Components.

1) Microcontroller

Node MCU is an efficient microcontroller that includes firmware with ESP8266 Wi-fi and is built around ESP8266 chip, which can link items and allow data transfer using the Wi-fi protocol.

2) Temperature sensor

The humidity and temperature readings from the DHT11 temperature sensor, which measures both, are produced by a controller using a thermistor with a negative temperature coefficient (NTC) for temperature measurement.

3) Piezo electric sensor

This sensor effectively converts the mechanical energy into electrical energy by the pressure applied by the patient to the sensor, it consists of positive and negative plates embedded so that the electron charges travel to the positive side when the pressure is applied.

4) Gyroscopic Sensor

MPU-6050 measures the angles made by the movement of the bone, it consists of a ball inside the sensor so that the movement is accurately measured. It measures 2 to 3 angles respectively (namely x, y, z axis)

5) OLED display

This component can be directly connected to the microcontroller, which basically displays the output fed from the circuit. It is different from normal LED and LCD display, because it has much higher display capacity i.e, contrast and brightness, which is called as an Organic Light Emitting Diode (OLED)

6) Battery (Power Supply)

Since it is a wearable device, a rechargeable battery is connected so that it can be made portable and does not require any external power supply each time when it is used, it can charged for a periodic basis only a minimal amount of time is required for charging. Lithium-ion battery is used in this circuit since the components in this requires and can run with only minimal power.

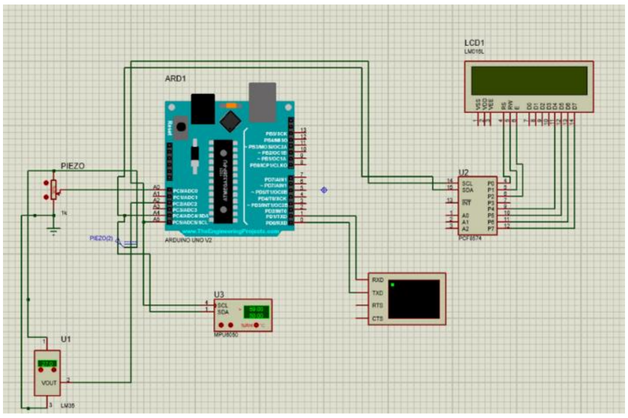

Fig 2. Circuit diagram of the proposed system

To detect vital parameters by DHT11 sensor, Piezoelectric sensor and a Gyroscopic sensor is used and they are connected to the analog pins of the microcontroller. These observed data are saved in the cloud for additional diagnosis, and the outcome is shown in an LCD as it is demonstrated in fig 2.

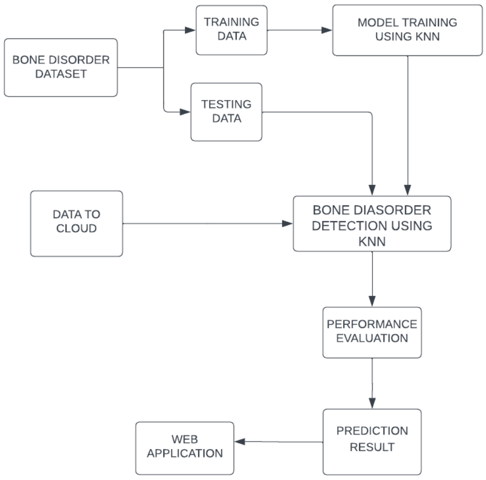

Fig 3. Block diagram of proposed system- Software

The results from cloud are sent to the training using machine learning algorithm after training the model file which is created in local for further classification using KNN algorithm. After the model file creation, the test data is sent and classified. Then the classified results are compared to acquire data with high accuracy, then the final result will be displayed in web application as shown in figure 3.

D. Steps of Proposed System

1) Data Acquisition:

Bone disorder data set is taken from Kaggle and the attributes of this datasets are,

Angle : Joint Angle (X,Y,Z) Pressure : Pascal (Pa)
Temperature : °C(degree Celsius)

2) Evaluation and Classification of data:

The data is evaluated by confusion matrix and evaluated matrix. The internal datasets are divided into training (80%) and test (20%) datasets. In this, test data is classified with the help of Activation function which performs as a decision function. Finally, the patient with Bone Disorder will be determined.

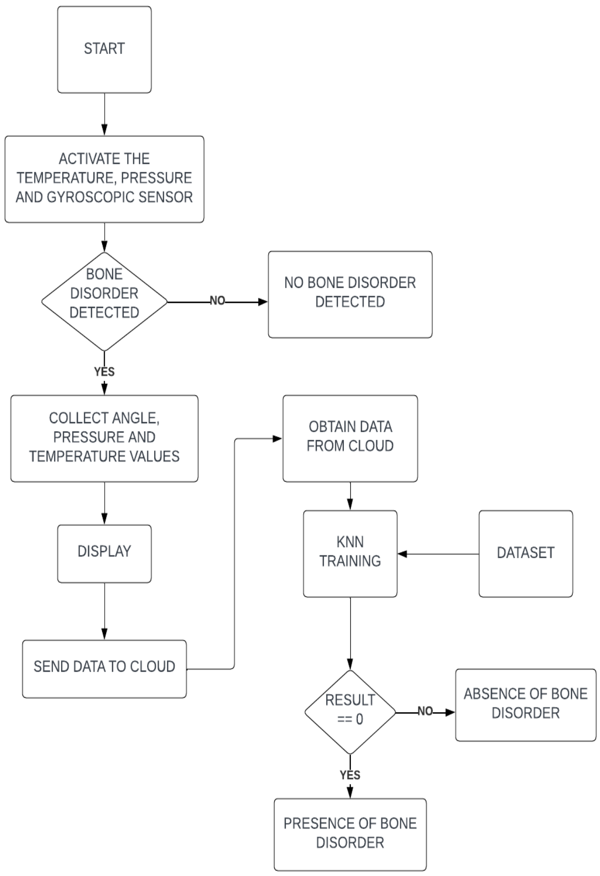

Fig4.Work flow of Proposed System

E) Evaluated Metrics

TN, TP, FN, FP are True Negative, True Positive, False Negative, False Positive respectively in confusion matrix.

Accuracy: Accuracy is used to determine how well a Machine Learning algorithm performs its function (i.e., in this prediction of Bone disorder accurately).

Accuracy= TN + TP / TN + FP + FN +TP

Specificity: machine learning specificity is the TN coherence that the successful detection of model (TNR)

Specificity= TP/FN+TP

Sensitivity: the recognition of the cases which are positive in called the sensitivity of machine learning

Sensitivity= TN / TN + FP

Precision: Precision is the coherence of Positive samples to all samples that are detected as Positive and it also determines how correctly a sample is categorized as positive by the model.

Precision = TP / TP + FP

Recall: Recall is used to measure how precisely it determines whether a sample is positive. The high the value of recall, the more positive samples identified.

Recall = TP / TP + FN

F1 Score: It is the average of precision and recall value is known and it is a method used to combine the properties of these two.

F1 Score = 2 * (Precision * Recall) / (Precision + Recall)

IV. RESULT AND DISCUSSION

A. *Result Analysis- Confusion Matrix*

TP=47	FP=0
FN=0	TN=53

In this matrix, FN doesn't give exact result (i.e., it didn't show the abnormal as normal). TP gives exact result (i.e., it didn't show that normal as normal).TN gives wrong result for 53 times (i.e,. it shows that the abnormal as abnormal). FP gives correct result for 0times (i.e., it shows as the abnormal as normal). So, the accuracy of KNN is shown in Fig 6.

TABLE I: THRESHOLD VALUE OF EACH PARAMETER

PARAMETERS	X	Y	Z	TEMPERATURE	PRESSURE
THRESHOLD VALUE	7-9	0	1-7	40	30-70 Pa

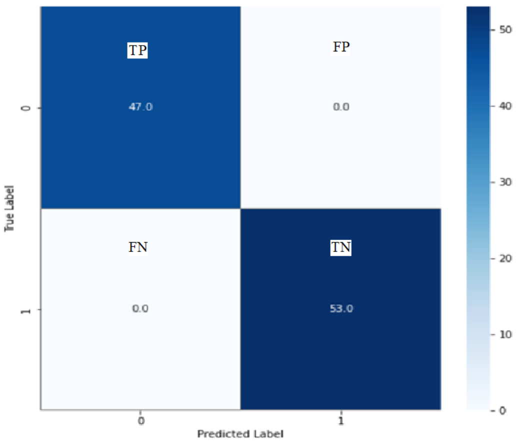

Fig 6. Confusion Matrix of K-Nearest Neighbour

TABLE II: OBSERVED RESULTS

X	Y	Z	Temperature (ºC)	Pressure (Pa)	Target
11.3307	-0.4905	-0.9115	32.136	5	0
11.5883	-0.3045	-0.9522	33.408	5	0
12.5863	-0.4717	-0.8667	31.2899	2	0
11.2101	-0.3005	-0.842	29.6036	8	0
12.2066	-0.3925	-0.9221	33.022	8	0
2.5974	0.3129	-9.0624	33.6935	113	1
5.4922	0.3912	-9.2299	29.7869	107	1
6.3643	0.4497	-9.5738	29.3986	134	1
0.8748	0.4241	-9.5454	31.028	81	1
4.999	0.4397	-8.3501	32.4377	150	1

0 – Bone Disorder	1 - Normal

Table 1 Illustrates the dataset value and the real time value observed for both normal individual and one with the bone disorder.

TABLE III: KNN Algorithm

ALGORITHM	ACCURACY	SPECIFICITY	SENSITIVITY	PRECISION	PRECALL	F1 SCORE
K-NEAREST NEIGHBOR	92%	0.8	1	0.9	0.86	0.9

Table II gives the average above ML technique (KNN) and it demonstrates the KNN algorithm, with bone disorder prediction accuracy of 92%

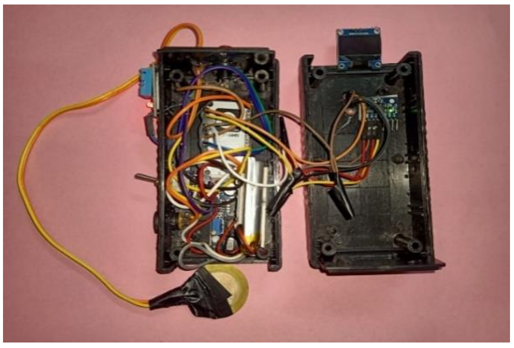

Fig 5. Prototype of Proposed System

In this Lithium ion battery is used which has 3.7V but all other components used here has 5V, so to boost the voltage boost convertor is connected to the battery and microcontroller. Various sensors are connected to the microcontroller to detect the angles, pressure and temperature sensor with a0 of the microcontroller.

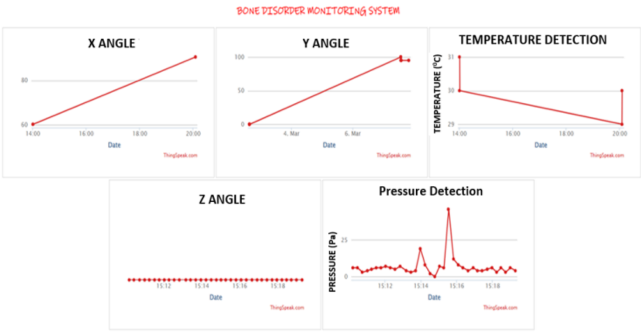

Fig 7. Result in Web Application

In the Web Application the final result will be displayed shows the parameters of the patients like angle, temperature, pressure to find whether the patient has bone disorder or not as shown in fig 7.

IV.CONCLUSION

A new system has been created for classifying knee joint health based on angles and pressure measurements and it relies on a small piezoelectric sensor during a knee extension/flexion test. This method has been effective in distinguishing between healthy and damaged knees as evidenced by prior research. The device is versatile and could be used in clinical environments or even in home-based preliminary screening. The system is reliable, precise, cost-effective and non-invasive, making it a practical option for assessing knee joint health. By implementing this technology in medicine, healthcare monitoring can be done in real-time, promoting more effective care. This advancement has significant potential in various medical fields.

In the proposed method machine learning algorithm has been used. K- Nearest Neighbor algorithm for bone disorder detection gives better accuracy. Out of a dataset of 200 samples from Kaggle, 70% has been taken for training and 30% for testing, The proposed system acquired 92% of accuracy. The Web Application displays the patient's current health status in the form of graph following the collection of the patient's vital information such as pressure, angle value and temperature from the cloud. Since the hardware is portable, it can be employed to analyze the health condition of a person anywhere by the individual themselves.

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