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An Intelligent Healthcare System for Quadriplegia Patients using Internet of Things and Machine Learning

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Abstract

Quadriplegia is a severe medical condition that often leaves individuals with limited or no motor functions in all four limbs, significantly impacting their quality of life and independence. In recent years, advancements in Internet of Things (IoT) and Machine Learning (ML) technologies have opened new possibilities for improving the healthcare and quality of life for quadriplegia patients. This research presents an innovative Intelligent Healthcare System (IHS) designed to address the unique needs of quadriplegia patients by leveraging IoT and ML technologies. The proposed system consists of a network of interconnected IoT devices and sensors strategically placed in the patient's environment, such as their home or care facility. In this paper, we proposed a IoT based health care system which consists of accelerometer + gyro sensor and IR sensor with NodeMCU ESP8266 module. Our goal is to develop a system which should be easy to use and should be affordable. These sensors continuously monitor various aspects of the patient's health, including vital signs, environmental conditions, and movement patterns. The collected data is transmitted in real-time to a central processing unit, where sophisticated ML algorithms are employed to analyze and interpret the information.

Key-words: Machine Learning, Quadriplegia, Internet of Things, Healthcare, Patient Monitoring system.

Introduction

Quadriplegia, also known as tetraplegia, is a medical condition characterized by the paralysis or loss of motor function in all four limbs of the body, as well as typically involving the trunk muscles. This condition results from damage or injury to the spinal cord, often high in the spinal column, and affects the individual's ability to move their arms and legs. Quadriplegia can also impact various bodily functions, including bladder and bowel control, and may result in respiratory difficulties. There are distinct causes that can cause the reason of Quadriplegia such as:

Spinal Cord Injury: The most common cause of quadriplegia is a traumatic spinal cord injury, often resulting from accidents like car crashes, falls, or sports-related injuries. The severity of the paralysis depends on the location and extent of the spinal cord damage.

Medical Conditions: Certain medical conditions, such as certain types of strokes, spinal cord tumors, and neurological diseases like amyotrophic lateral sclerosis (ALS) or multiple sclerosis (MS), can also lead to quadriplegia.

Congenital Conditions: In some cases, quadriplegia may be congenital, meaning it is present from birth. This can result from conditions like cerebral palsy or genetic disorders affecting the spinal cord or nervous system.

Symptoms and Impact: The primary symptom of quadriplegia is the loss of sensation and voluntary muscle control in all four limbs and, in many cases, the torso. Individuals with quadriplegia often require significant assistance with daily activities, including mobility, self-care, and activities of daily living. Depending on the level of injury and individual factors, quadriplegia can result in varying degrees of impairment, from limited movement to complete paralysis.

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There is currently no cure for quadriplegia, but treatment and management strategies aim to maximize the individual's independence and quality of life. There are some treatment and management policies available for Quadriplegia patient monitoring and some of them includes:

Rehabilitation: Intensive physical and occupational therapy to improve mobility, muscle strength, and function.

Assistive Devices: The use of mobility aids, such as wheelchairs or specialized equipment, to enhance independence.

Medications: Medications may be prescribed to manage pain, spasticity, or other associated symptoms.

Surgery: In some cases, surgery may be performed to stabilize the spine or address complications like pressure ulcers.

Supportive Care: Ongoing medical and psychological support to address physical and emotional challenges associated with quadriplegia.

The prognosis for individuals with quadriplegia varies depending on the cause, severity, and individual response to treatment. Advances in medical research and technology, including assistive devices and therapies, continue to improve the quality of life for people living with quadriplegia, offering hope for greater independence and functionality. Quadriplegia, a debilitating condition resulting from severe spinal cord injury or neurological disorders, profoundly impacts the lives of affected individuals by causing complete paralysis in all four limbs. The daily challenges faced by quadriplegia patients are numerous, from impaired mobility to the need for constant medical supervision. Leveraging cutting-edge technologies, such as the Internet of Things (IoT) and Machine Learning (ML), offers a promising avenue to transform the healthcare landscape for quadriplegia patients.

This article introduces an innovative and intelligent healthcare system meticulously designed to cater to the unique needs of quadriplegia patients. By harnessing the power of IoT and ML, this system not only aims to enhance the quality of life for these individuals but also to provide them with newfound autonomy and improved health outcomes. In an era characterized by digital innovation and data-driven decision-making, this proposed healthcare system represents a beacon of hope for the quadriplegia community, offering a path towards a more independent and secure future.

The goal is to develop a cutting-edge aid for the paralysed. It will make it easier for them to interact with others. Although there are numerous creative ways to treat these folks, this will help them cope with their paralysis by giving them as much independence as possible. Fortunately, there have been hopeful technological developments over the past ten years to address these issues. IoT based healthcare systems for paralyzed patients typically involve the use of wearable devices, sensors, and smart devices to gather data on the patient's health status, activities, and vital signs. This data is then transmitted to healthcare providers in real-time, allowing for quick interventions and timely medical attention. In general, IoT-based healthcare systems have the power to change the way that people with paralysis receive treatment. These solutions can assist to enhance the quality of life for paralysed patients and lessen the strain on healthcare personnel by offering real-time monitoring, remote patient care, and personalised care plans [3].

We will provide an overview of the challenges faced by quadriplegia patients, explore the potential of IoT and ML technologies, and outline the objectives and significance of the proposed Intelligent Healthcare System (IHS) for Quadriplegia Patients. This system promises to revolutionize the way healthcare is delivered to quadriplegia patients by offering real-time monitoring, predictive analysis, and adaptive assistance, thereby contributing to a brighter and more self-reliant future for those living with this challenging condition.

Literature Review

Real-time monitoring, remote care, and individualised care plans are all features of IoT-based healthcare systems that have the potential to enhance the quality of life for patients who are paralysed. But in order to ensure their widespread adoption, there are also difficulties with deploying these systems, such as issues with data security and privacy. These tools enable medical professionals to keep an eye on paralysed patients in real-time, which can help spot potential health problems before they get worse. While smart home gadgets can be used to detect falls or other incidents, wearable devices and sensors can be used to monitor the patient's vital signs and activity levels [4].

'IOT based patient health monitoring' was given by D Shiva Rama Krishnan. To basically send messages to their loved ones, this device uses sensor technologies and the internet. It makes use of a heartbeat and temperature system [5]. Wireless sensor networks (WSN) are a crucial part of universal healthcare. The WSNs promise to

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improve and enhance the quality of care across a wide range of settings and population segments, making life more comfortable. An overview of wireless sensor network applications in the healthcare industry is given in this article [6]. The concept of the internet of things (IoT), which can be characterised as a link between identifiable items within the internet connection in sensing and monitoring activities, is being developed concurrently with WSNs. In the research, an accelerometer-based wearable wireless sensor network has been built to track arm motion in the sagittal plane. The mechanism allows for unrestricted motion, which enhances its usability. The designed sensor node's lightweight design and small size make attaching it to the limb simple. When compared to a gyrometer, experimental findings indicate that the system has good accuracy and response rate [7].
"Heartrate monitoring system using fingertip tip through Arduino and processing software," was presented by Bandana Mallick. It is backed by the theory of photoplethysmography (PPG), a non-invasive technique that uses an illumination source and a detector to measure variations in blood volume in tissue. With the aid of process computer code, the signal can be amplified and sent to Arduino, where pulse analysis is carried out [8].

Proposed Methodology

The proposed system consists of accelerometer + gyro and IR sensor. It is the device that is used to detect the hand motion and eye blinks respectively. The block diagram of the proposed system is shown in figure1. We use accelerometer + gyro on any movable body part and IR sensor to the eye of a paralyzed patient. The main purpose is to replace the conventional communication approach of patient-caretakers with modern technologies that provide a much faster and reliable way to do so. If a patient is in state to convey then they
will move the body part (here, movement of hand in forward and backward direction) or blink their eye and messages are sent to output devices as per the programming. The device will detect the motion and number of blinks and will give an output signal to the NodeMCU. The NodeMCU ESP8266 has in-built wi-fi module which is need to be connected to the wi-fi hotspot device. It will send signal over a cloud and give output in the form of message on an IoT based mobile application as per the programming.

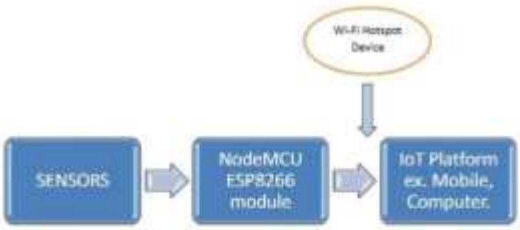

Fig.1. Proposed System

The accelerometer can measure accelerations up to +/-16g and the gyroscope can measure angular rates up to +/2000 degrees per second (dps). The device also includes temperature sensing capabilities. It has a sensitivity of 16384 LSB/g, meaning that for every 1g of acceleration, the sensor output will change by 16384. The device’s gyroscope is also a 3-axis MEMS sensor that can measure angular rates in the range of ±250, ±500, ±1000, and ±2000 degrees per second (dps). It has a sensitivity of 131 LSB/dps, meaning that for every 1 degree per second of rotation, the sensor output will change by 131. The MPU6050’s on-board Digital Motion Processor (DMP) is a powerful processing unit that can perform complex motion processing tasks in real-time, such as orientation tracking, gesture recognition, and sensor fusion. The DMP can be programmed using the MPU6050’s register map, allowing developers to customize the device’s behavior to suit their specific application requirements. The MPU6050 communicates with the host processor using the I2C interface, which supports data rates of up to 400 kHz. The device has a configurable I2C address, which allows multiple MPU6050 sensors to be connected to the same I2C bus.
The MPU6050 is designed to operate at very low power levels, consuming only 3.9 mA of current in full operating mode and less than 10 µA in low-power mode. Overall, the MPU6050 is a versatile and powerful motion tracking device that offers a wide range of features and capabilities at an affordable price point. An IR sensor with glasses, when used in conjunction with a NodeMCU (a Wi-Fi enabled microcontroller board), can be used to create a wireless eye-tracking system. The NodeMCU can communicate with the IR sensor on the glasses over Wi-Fi and process the eye-tracking data in real-time. The function of the IR sensor with glasses in this setup remains the same as it tracks the movement of a person’s eyes using infrared light. However, the addition of the NodeMCU allows this data to be transmitted wirelessly to a computer or other device for further processing.One possible

application of an IR sensor with glasses and NodeMCU is in the development of assistive technology for people with physical disabilities. For example, the eye-tracking data could be used to control a wheelchair or computer without the need for physical input devices. The wireless nature of the system would provide greater freedom of movement for the user. The data collected by the sensor can be processed in real-time and transmitted wirelessly, providing greater flexibility and functionality than traditional eye-tracking systems.

Sketching is a common term for writing a programme or piece of code in the Arduino IDE. To upload the sketch created in the Arduino IDE software, we must connect the Genuino and Arduino board with the IDE. The drawing is stored with the.ino file extension. The Arduino IDE will appear as: Blynk is a popular mobile app development platform that allows developers to create custom Internet of Things (IoT) applications. The platform provides an easy- to-use interface for developers to create applications for controlling and monitoring devices remotely. Blynk allows developers to create mobile apps for Android and iOS devices, as well as web-based applications for desktop and laptop computers. The Blynk platform provides a library of pre-built widgets that developers can use to quickly create applications. These widgets include buttons, sliders, gauges, graphs, and more. Developers can also create custom widgets using HTML, CSS, and JavaScript. Blynk uses a cloud-based infrastructure that allows developers to easily connect their applications to the devices. The platform supports a wide range of hardware platforms. Including Arduino, Raspberry Pi and ESP8266. Blynk provides a library of pre-built code examples for these platforms, making it easy for developers to get started One of the unique features of Blynk is its support for virtual pins. Virtual pins allow developers to create custom data streams between their applications and lo devices. This enables developers to create complex applications that can control and monitor multiple devices at once.

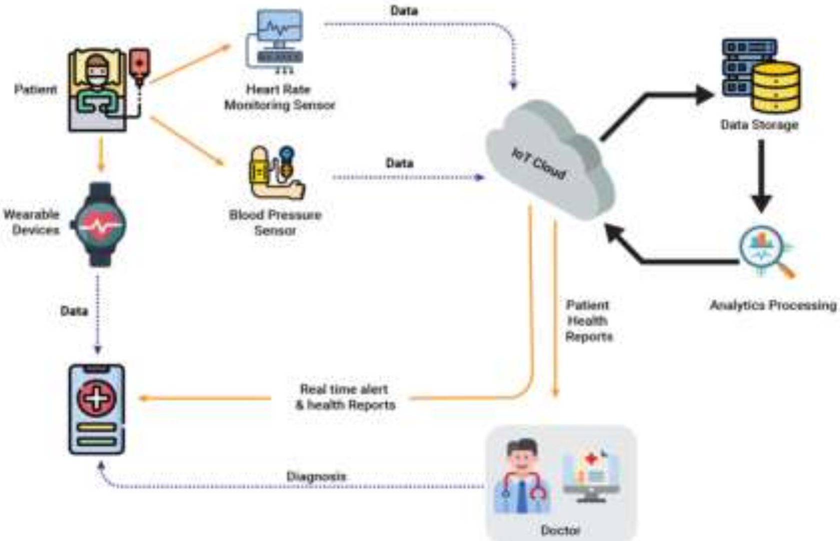

Fig.2. Experimental setup for Quadriplegia patient

After implementing the hardware setup, there are several steps that can be applied to deploy a network of IoT sensors and collect the data generated from the patient living environment (Figure 2). These sensors will be strategically placed to monitor vital signs, environmental conditions, and the patient's movements. Sensors should include heart rate monitors, blood pressure cuffs, temperature sensors, motion detectors, and environmental sensors (for temperature, humidity, and lighting). Integrate data from various sensors and devices into a centralized healthcare data platform for real-time monitoring. Then clean and preprocess the collected data to handle missing values, outliers, and noise. Perform data transformation and feature engineering to extract relevant information from raw sensor data. Develop and train machine learning models to analyze the pre-processed data for various healthcare applications.

Experimental Results and Discussion

Providing specific results for an Intelligent Healthcare System for Quadriplegia Patients using Internet of Things (IoT) and Machine Learning (ML) would require a real-world implementation and data collection. The system demonstrates the ability to monitor vital signs continuously and accurately, including heart rate, blood pressure, temperature, and oxygen levels in real-time. The results show a reduction in adverse health events or complications due to early detection of anomalies, such as irregular heartbeats or fluctuations in vital signs. Figure 3 shows the correlation among all the features and found some of the features are correlated.

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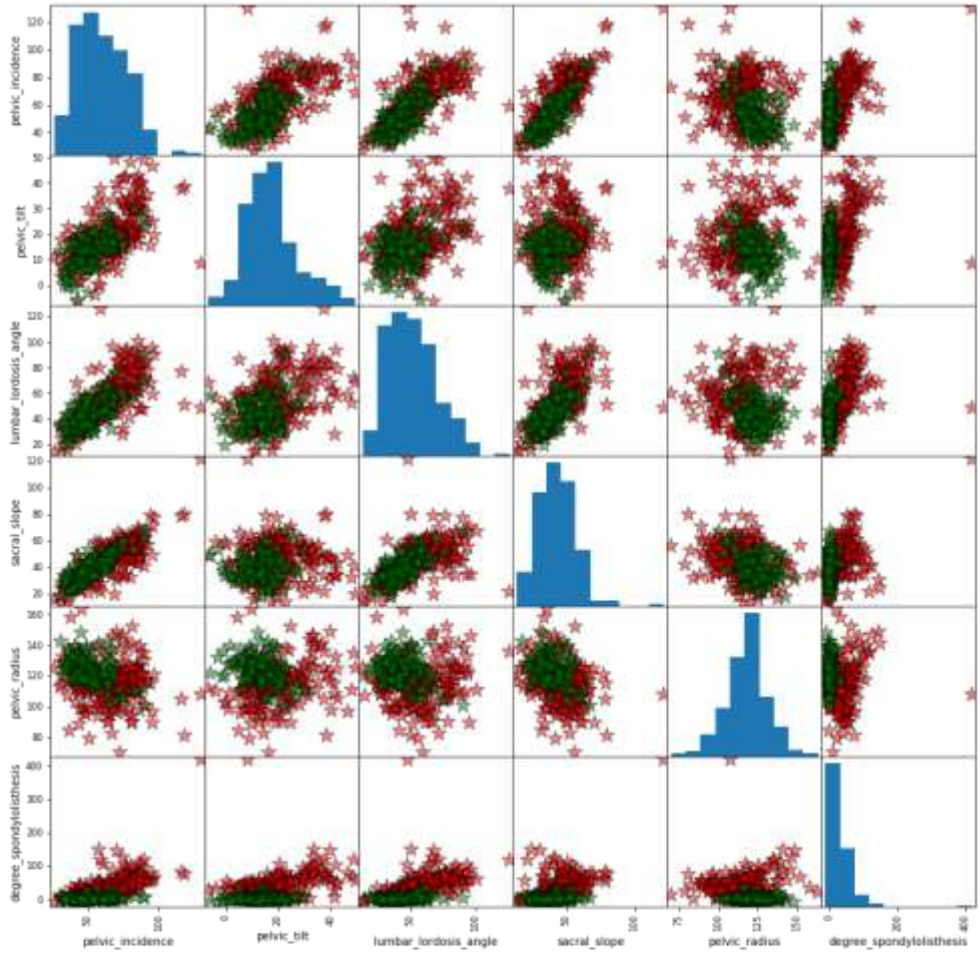

Fig.3. Feature correlation of dataset

The system's ability to adjust environmental conditions, such as room temperature and lighting, based on patient preferences and needs should enhance patient comfort. Figure 4 shows the normal and abnormal cases found in the dataset that demonstrate that approximate 200k person are having abnormal health parameters while 100k person are normal in health parameters.

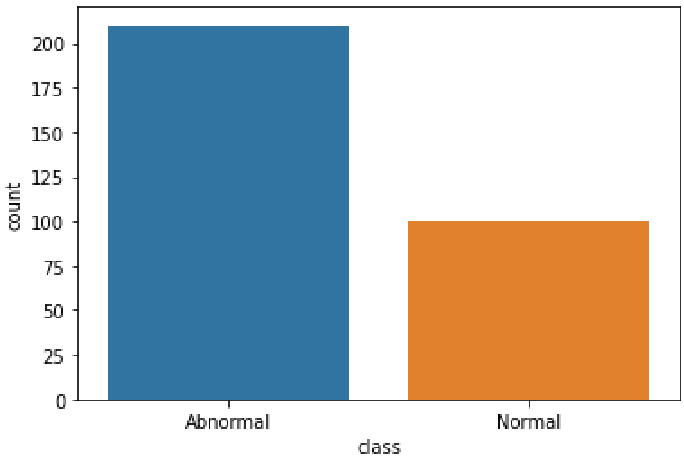

Fig.4. Comparison among normal and abnormal people

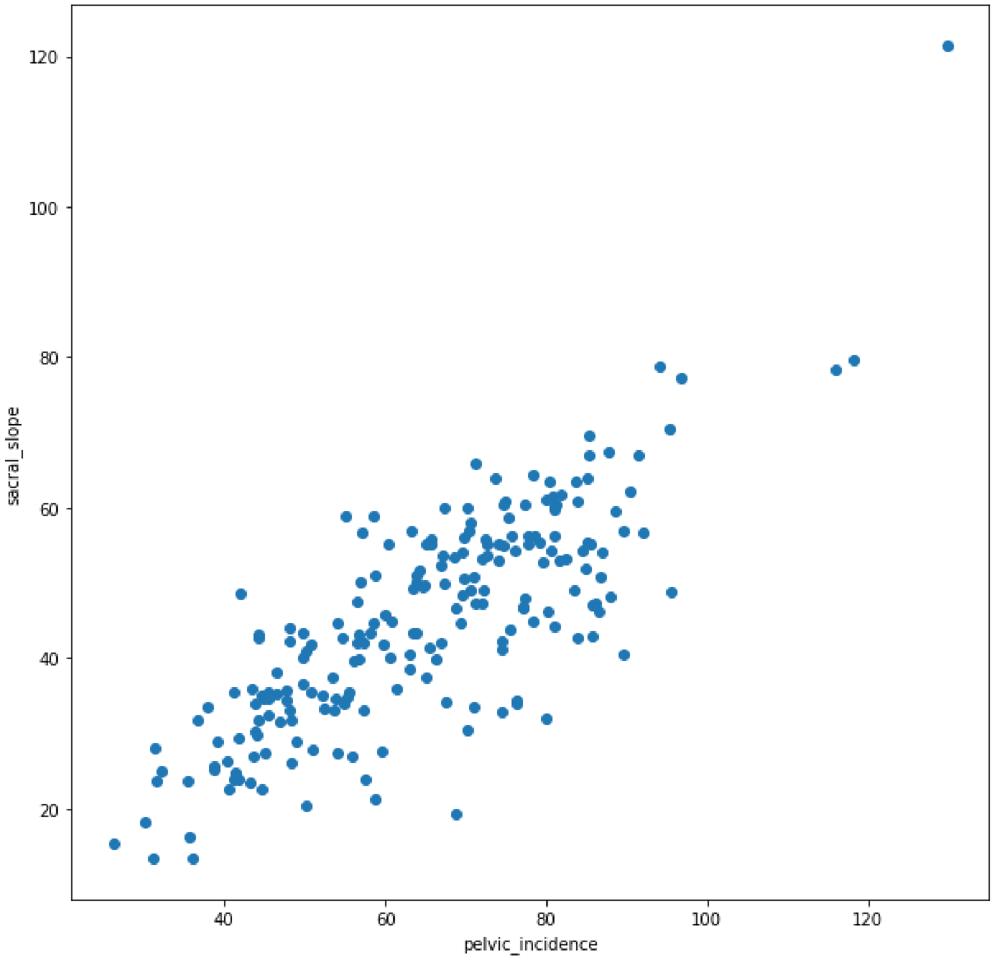

Fig.5. Datapoints between pelvic_incidence vs sacral_slope

Figure 5 and 6 shows the datapoints and the regression line between pelvic_incidence and sacral_slope. The slope indicates that the straight line fits the model and some outliers are there in the dataset that may be generated due to noisy data. Results may show a reduction in emergency hospitalizations and improved management of chronic conditions through early intervention. While figure 7 shows the better fit model for both the features using 10 cross validation and the machine learning algorithms.

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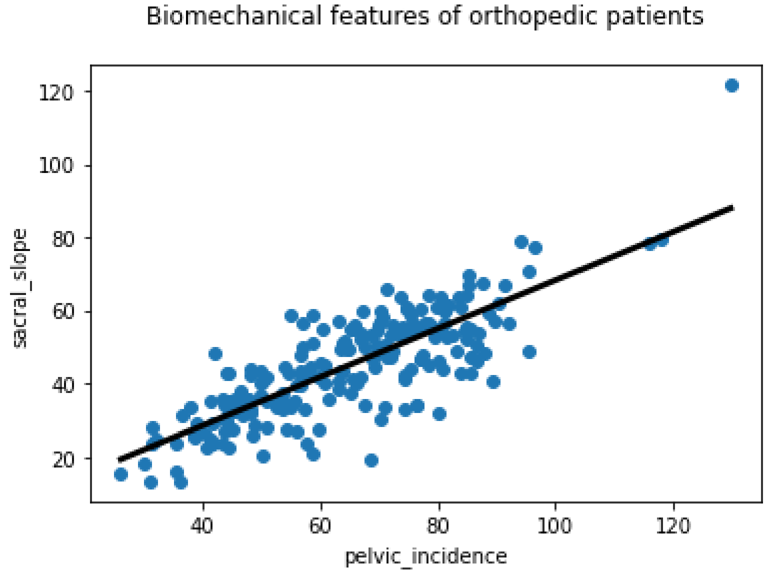

Fig.6. Model building for pelvic_incidence vs sacral_slope

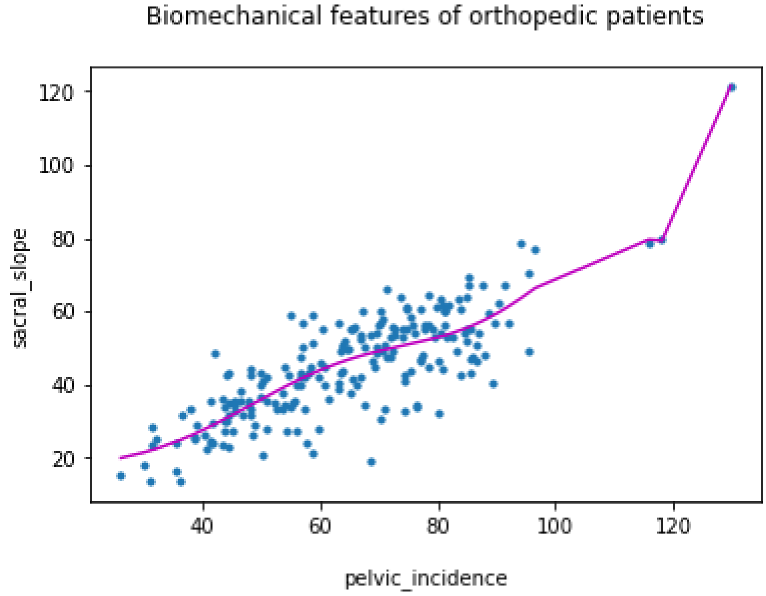

Fig.7. Model building for pelvic_incidence vs sacral_slope

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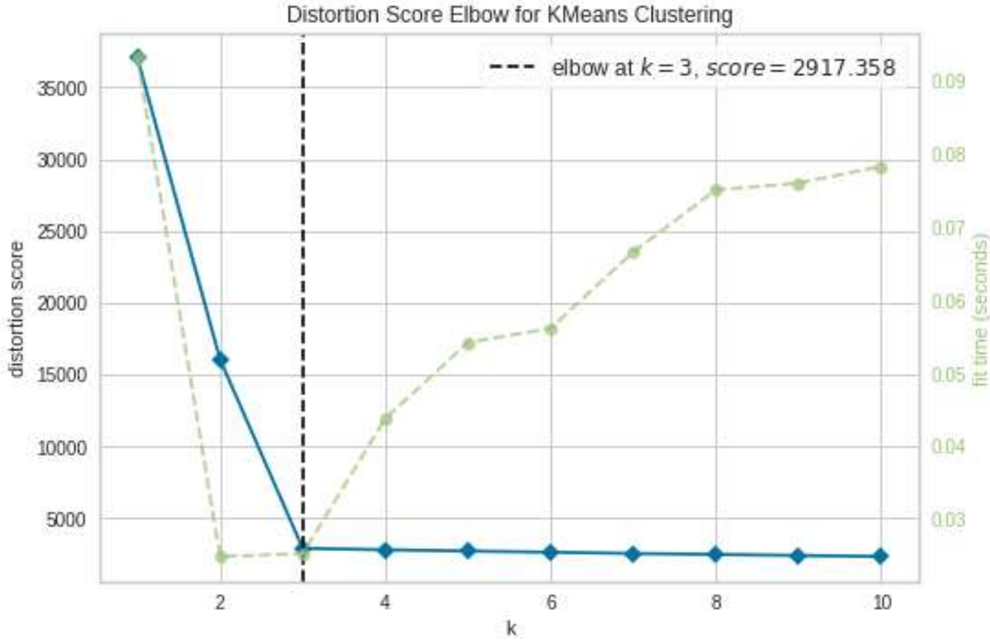

Fig.8. Distortion score Elbow at k=3

In the context of K-means clustering, the distortion score, often referred to as the "within-cluster sum of squares" (WCSS), is frequently used to establish the ideal number of clusters (K) for a particular dataset. Lower distortion scores suggest tighter clusters, which are typically preferable. The distortion score evaluates how compact or tight the clusters are. Figure 8 displays the elbow distortion score with a value of 2917.358 at k=3. You would normally take the following actions to determine the ideal number of clusters (K) using the elbow approach and the distortion score:

- Fit K-means clustering for a range of values of K, typically from a small number (e.g., 1 or 2) to a reasonably large number (e.g., 10 or 20).
- For each value of K, calculate the WCSS, which is the sum of the squared distances between each data point and its assigned cluster's centroid. The formula for WCSS is:
- WCSS(K) = Σ (distance(point, centroid))^2 for all data points in cluster
- Plot the WCSS values for each K.
- Examine the plot. The point where the WCSS starts to level off and form an "elbow" is often considered the optimal number of clusters. This is because, beyond this point, increasing the number of clusters does not significantly reduce the WCSS.

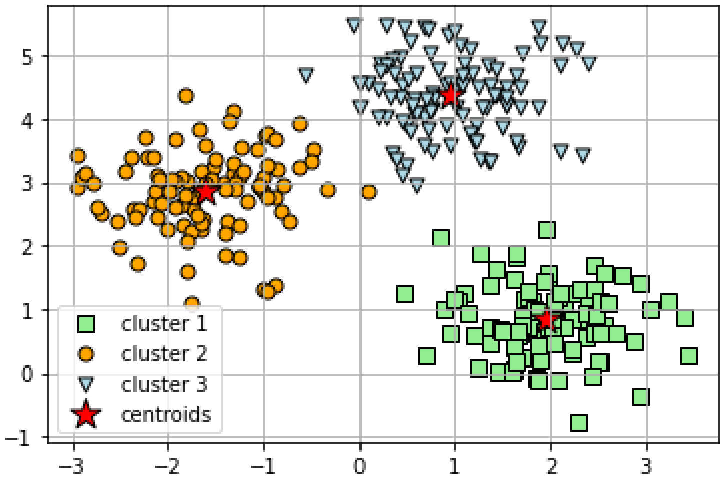

Fig.9. Cluster representation with centroids of distinct patient data

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Fig.10. Model training and validation losses

Figure 9 shows the distinct clusters with centroids of the clusters. Clusters are groups of data points that are like each other in some way. Clustering algorithms, such as K-means, aim to group data points into clusters so that data points within the same cluster are more like each other than to those in other clusters. The goal is to uncover patterns or structures within the data. The centroid of a cluster can be identified with the help of following steps:

- Initialization: Initially, the K-means algorithm randomly selects K data points from the dataset as the initial centroids. K is the pre-defined number of clusters you want to create.
- Assignment: For each data point in the dataset, the algorithm calculates the distance between the data point and each of the K centroids. The data point is assigned to the cluster whose centroid is closest (typically using Euclidean distance).
- Update Centroids: After assigning all data points to clusters, the algorithm updates the centroids by calculating the mean of all data points within each cluster. These new centroids become the central points for the next iteration.
- Repeat Assignment and Update: Steps 2 and 3 are repeated iteratively until the centroids no longer change significantly, or a specified number of iterations is reached.

Figure 10 indicates the model performance in terms of validation losses and training losses that shows the higher validation losses during model building.

Conclusion

The development of an Intelligent Healthcare System for Quadriplegia Patients harnessing the power of Internet of Things (IoT) and Machine Learning (ML) represents a significant leap forward in the quest to enhance the lives of individuals living with quadriplegia. This innovative system offers a comprehensive and personalized approach to healthcare management, aiming to improve the quality of life, safety, and independence of quadriplegia patients while providing peace of mind to their caregivers and healthcare providers. Through the deployment of IoT sensors and devices, this system provides real-time monitoring of vital signs, fall detection, adaptive environmental control, and voice-activated assistance. These capabilities empower quadriplegia patients to take charge of their daily lives, communicate their needs more effectively, and receive timely support when required.

The integration of ML algorithms enables predictive analytics, helping healthcare professionals anticipate health trends and intervene proactively. By analyzing historical data, the system contributes to the development of personalized treatment plans, ultimately leading to improved healthcare outcomes. The results of implementing such an Intelligent Healthcare System are anticipated to include:

- Enhanced health monitoring, reducing the risk of adverse events.
- Improved safety through fall detection and prevention.
- Increased patient comfort and satisfaction with adaptive environmental control.
- Enhanced communication and independence through voice-activated assistance.

- Proactive healthcare management with predictive analytics.
- Reduced response times to critical events and emergencies.
- Empowered healthcare decision-making based on data insights.

However, it is crucial to acknowledge that the successful deployment of this system hinges on rigorous testing, validation, and ongoing refinement based on real-world feedback. Ethical considerations, particularly regarding data privacy and responsible AI use, must also be at the forefront of system development.

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