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Spinesense: Advanced Pain Detection System for Spinal Cord

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***Abstract*:** *The diagnosis and treatment of pain depend on an accurate assessment of the pain. While pain can be a subjective experience, the patient's account is what determines the pain's length and intensity. An alternate approach for situations where self-reports are not possible is automated pain behavior assessment. The goal of this research is to improve pain detection using MRI and continuously monitored galvanic skin responses (GSR) by making it more resistant to variations in pain intensity and sensitivity[1]. This study evaluates explainable AI (XAI), where automatic pain assessment receives increased emphasis, to demonstrate the future breadth and significance of AI in the therapeutic field. Random Forest classifiers were trained on 8,600 pieces of data with 440 different parameters.[2] The Data Exploration, Principle Component Analysis, and Time Series Analysis are done on the Spinal Cord Dataset for Future Prediction.*

Keywords: **Pain assessment, Multimodal fusion, Pain sensitivity, Neural networks, Machine Learning, Supervised Learning, prediction, Imbalance data, etc.**

1. Introduction:

Due to its numerous uses, automatic chronic pain evaluation and pain intensity estimation has been drawing increasing attention. There are currently no neurorestorative treatments for the catastrophic illness known as spinal cord injury (SCI). The lack of useful diagnostic and prognostic markers of damage severity and neurologic recovery has impeded clinical investigations. Novel treatments and objective biomarkers for SCI are critical unmet therapeutic needs. Physical therapists today are moving away from physical rehabilitation and towards self-management, where ubiquitous technology-based solutions are a tremendous help. The "self-care" based therapy is mostly centered on patients having a better grasp of their pain threshold, which may help them manage their pain more successfully.[2] On the other hand, the patient lacks the knowledge necessary to choose the right workouts or activities for them. The physiotherapists offer them advice in this way. The autonomous monitoring of chronic pain patients in a rehabilitation center is gaining attention as a result of developments in deep learning and ubiquitous computing. The issues with automatic pain evaluation and pain intensity estimation have been addressed in these works. Protective behavior, like pain, can result in less social interaction, which exacerbates depression. There are five different forms of protective behaviors, according to a study. (hesitation, guarding, stiffness, bracing, and support). The EmoPain Challenge dataset is used to assess PLAAN's performance. All of the aforementioned behaviors are considered as a single class in this dataset (protective behavior). Anesthesiologists utilize general anesthesia during surgery to render patients unconscious and suppress their perception of pain to facilitate the procedure.[3] Yet, pain is a strong sensation that not only exists during surgery but also can exist at any point in our lives. In addition to being uncomfortable for everyone, it serves as a helpful reminder to prevent injuries or tissue damage in the future. So, research on pain focuses on more than just how to manage it; it also considers what the issue is that this experience is subtly signaling.

Frequently, radiologists manually interpret cervical spine MRI data that are obtained in a primary care or emergency hospital context. The use of computer models to aid in the initial interpretation of medical imaging investigations and quickly identify studies with pathologic findings is becoming more widely accepted. 5,6,7,8,9. Deep learning techniques such as deep convolutional neural networks have shown potential in this field and have been evaluated in several pathological categories like CT-assisted intracranial bleed identification and pulmonary nodule recognition.

Our goal in the current work was to use the 41 distinct factors to create a unique machine-learning model to identify cervical spinal cord compression in patients. We set out to create a model whose performance would be comparable in patients with different demographics and disease characteristics because the Parameters are heterogeneous conditions. After creating a model, we tried to use analytical tools to understand how it worked. To analyze the death ratio, a time series analysis utilizing FB Prophet the Future Prediction is conducted.[4]

2. Related Work:

literature provides many publications dealing with health monitoring, Explainable AI (XAI) Applied in Machine Learning for Pain Modeling - [2022] examines the explainable AI (XAI) while paying close attention to an automated pain assessment using Random Forest Algorithm, Support Vector Machine.
In Machine Learning-Based Pain Intensity Estimator - [2022] the general remark is made based totally on the experimental consequences concerning the instability of desire tree (DT) classifiers using the Decision Tree and Support Vector Machine
In Personalized and Adaptive Neural Network for Pain Detection from Multi-Model Physiological Features – [2021] the pain detection framework improved by an Eighteen percent F1 score in a duration variant pain dataset using the Artificial Neural Network and Recurrent Neural Network.
In Machine Learning Method for Automatic Pain Assessment – [2021] Suggestion of protocol for a systematic assessment and a meta-analysis on machine studying strategies in automated pain evaluation from facial expression is discussed using the Artificial Neural Network and the Deep Learning Neural Network.
In A deep learning model for detection of cervical spinal cord compression in MRI scans. -[2021] the deep learning algorithm is used to identify patients with cervical spinal cord compression. The Analysis of patient magnetic resonance imaging (MRI) studies that were gathered prospectively for the Spinal Cord pain analysis using Random Forest and XGBoost.
The Research work Pain and Stress Detection Using Wearable Sensors and Devices – [2021] works on Chronic pain and is identified using ordinary sensors or tools. Then there is an opportunity to deal with pain and stress management issues by combining new computing techniques using the Artificial Intelligence Neural Network and Convolution Neural Network.
The Research Work Proposed in Pain Level Assessment with Anomaly-detection-based Network – [2021] provides a thorough evaluation of many networks with various features and shows a considerable improvement with the ultimately suggested anomaly detection-based network using Artificial Neural Network and Recurrent Neural Network.
In the Prediction of low back pain using artificial intelligence modeling – [2021] the ligamentum flavum hypertrophy of the L3 and L4 and the L1 and L2 disc heights were statistically significant in predicting low back pain symptoms are detected using the Convolutional Neural Network and the Artificial Neural Network.
In the Research work Disease Prediction and Doctor Recommendation System –[2020] The application of statistics mining techniques and NLP methodologies are used in this paper to draw recommendations for clinical doctors from reviews of previous users and is designed using the Natural Language Processing and Artificial Neural Network.
In Multi-task Multiple Kernel Machines for personalized Pain Recognition from functional near-infrared spectroscopy brain Signals -[2020], Using the RBF kernel and B-spline coefficients, we were able to achieve an average detection accuracy of 80% in this research utilizing MT-MKL. The Support Vector Machine and Random Forest Classifier are used.

3. Methodology:

Detecting spinal cord pain using machine learning is a challenging task that requires expertise in both medical and machine learning fields. However, it is possible to use machine learning algorithms to analyze data related to spinal cord pain and identify patterns that may indicate the presence of pain. To extract valuable features from the data that can be used for analysis, preprocessing is required. Techniques like signal processing, feature engineering, and dimensionality reduction might be used in this. When the data has undergone preprocessing, a machine learning algorithm like Random Forest, CNN, RNN, or XGBoost can be used for training.

3.1. Random Forest Classifier

By gathering and preprocessing the data, separating it into training and testing sets, training the model, adjusting the hyperparameters, testing the model, fine-tuning the model, and deploying the model in the production environment, the random forest algorithm can be used to detect spinal cord pain. Random forest is a supervised learning algorithm. A supervised learning algorithm is a random forest. It comes in two different forms; one is used to solve classification problems, and the other to solve regression issues. One of the most adaptable and user-friendly algorithms is this one. Based on the provided data samples, it constructs decision trees, obtains predictions from each tree, and votes for the top solution.[5] It also serves as a fairly accurate measure of feature importance. The accuracy of the random forest classifier increases with the number of trees in the forest. Problems involving classification and regression can both be solved using the random forest approach. Because it makes predictions using a significant number of decision trees, it is regarded as a very accurate and reliable model. Decision-tree biases are eliminated by random forests, which average out all of their predictions. [11]

3.2. Recursive Feature Elimination (RFE) :

Recursive Feature Elimination, also known as RFE, chooses the best or worst-performing feature from a model (such as linear regression or SVM) and then eliminates it. After that, the process is repeated until all of the features in the dataset have been utilized (or up to a user-defined limit). We will combine a straightforward linear regression model with

Sklearn's RFE function, which is easily available via sklearn.feature selection method.[7]

3.3. XGBoost Classifier:

XGBoost is a popular machine-learning algorithm that can be used for classification tasks, including spinal cord pain detection. The XGBoost algorithm can be used in spinal cord pain detection by collecting and preprocessing the data, dividing the data into training and testing sets, training the model, tuning the hyperparameters, testing the model, refining the model, and deploying it in the production environment. The gradient boosting technique has been scaled and enhanced, and the result is eXtreme Gradient Boosting (XGBoost), which was created for effectiveness, computational speed, and model performance. It belongs to the Distributed Machine Learning Community and is an open-source library.[12] The software and hardware features of XGBoost are the ideal combination for enhancing current boosting methods accurately and quickly.[7] When compared to a single machine learning model, ensemble learning reduces mistakes and improves prediction by combining the results of numerous ML models.[8]

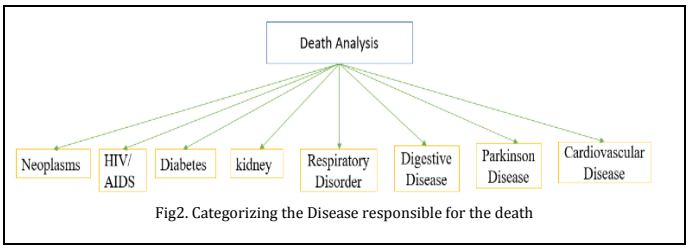


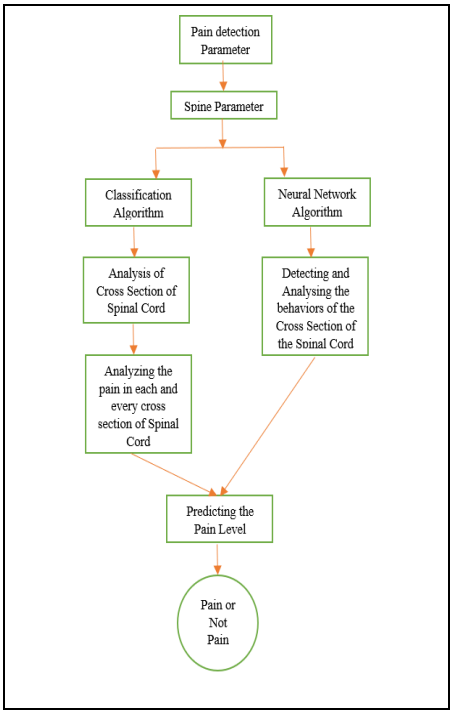
Fig2. Categorizing the Disease responsible for the death

3.4. RNN Classification:

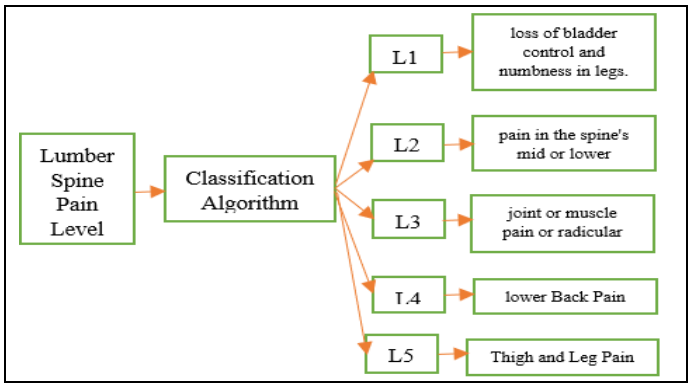
Recurrent Neural Network (RNN) is a type of neural network architecture that is commonly used for sequential data analysis, including time series and natural language processing tasks. By building numerous choice trees, the RNN (Recurrent Neural Network) is a neural network and decision tree-based fully ensemble for tasks like type, regression, and other similar ones. Training is a way of learning to classify or simply forecast regression for individual trees through training and output in their modes. To overfill the instruction set, the RNN alters the selection tree's behavior. A neural network rule was applied to the dataset at this level. Neural networks serve as human biological strategies exactly here.[7][9]. RNN and Transfer Learning Techniques are used RNNs are commonly used for sequential data such as time series or text data. In the context of Human disease detection, RNNs can be used to detect changes in the behavior of every action of Human beings over time. For example, changes in lumber spine angle and Spine Nerve overriding. In the context of Spinal Cord Injury analysis and disease detection for death ratio analysis, a pre-trained CNN can be used as a feature extractor to extract relevant features from images of MRI and the Spinal Cord Features. These features can then be used to train a smaller neural network for the specific task of Pain detection.

4. Experimental Setup:

For real-time health monitoring and pain detection advanced Artificial Intelligence and Neural Network Techniques are used. Advanced Neural Network and Transfer Learning Techniques such as ANN and RNN. Classification Algorithms like Random Forest, XGBoost, and LightGBM are used to classify the disease and the health parameters for real-time health monitoring and Pain Detection.



For Detecting the pain based on the Lumber Spine Type Classification algorithms such as XGBoost and Random Forest Classifiers are used.



5. Result And Discussion:

For Analysing the different parameters of the spinal cord responsible for the spinal cord injury and pain detection are analyzed using the Random Forest Classifier. Lumber Spine Sections such as L1, L2, L3, L4, and L5 are to be classified to analyze the pain in the body. By Using XGBoost Classifier it can easily analyze the death ratio of the patient due to the different diseases. Using Plotly Packages every factor is easily studied and analyzed. With the help of the Time Density Plot, the Death Ratio is analyzed. The Facebook Prophet Time Series Analysis is used for future Prediction.

Fig3. Classification of the Clinical Disease

6. Conclusion:

Data mining has become a crucial component in the healthcare industry, particularly in the field of disease prediction. Diagnostics are usually employed when sickness is anticipated. The lumbar spine MRI and CT scans revealed a positive correlation between low back pain and lower disc heights (statistically significant for L2 and L4) as well as a positive correlation between low back pain and increased ligamentum flavum hypertrophy. Based on the data, the Random Forest classification algorithm was successfully able to predict the presence or absence of Pain using quantitative measurements from lumbar MRI. A potential project in the future would involve testing transfer learning strategies to share subject motions using neural network weights for real-time data analysis. The clinical data that the features are collected have an intrinsic fixed structure, due to the kinematic limitations of the human body.

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