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Gesture Based Control Of Mechanical Arm Using Wearable IMU Sensors

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***Abstract*— Gesture has played an important role in reducing the gap between human and machine. Hand gesture recognition is applied in many technologies like games, wireless devices, mobile application, etc. In this paper, we have proposed a system in which the mechanical arm imitates the gesture performed by the operator using a wearable and machine learning algorithm for classification of gestures. The wearable is based on Inertial Measurement Unit (IMU) sensors which is gaining significant importance in field of Gesture Recognition. The classification algorithm used is Support Vector Machine which can recognize movement with less computation time and higher accuracy, and can also model non-linear relation with more precise classification using SVM kernels.**

***Keywords*— Gesture Classification, IMU sensors, Wearable device, Mechanical arm, Human-machine Interaction.**

I. Introduction

Human-Machine Interaction (HMI) is a widespread field based on communication between human and machine. HMI is the interaction between human and machine which is done by analyzing human behavior and appearance Various methods are proposed in human machine interaction. Some of them are through voice, keyboard, camera, etc. Gesture is one of the methods used for HMI which is a non-verbal communication method based on body movements. Inertial sensor based gesture recognition is gaining popularity because of its low cost, lightweight, low power design with great precision. Inertial measurement unit (IMU) consists of accelerometer and gyroscope responsible for finding the positioning of an object in 3D space. These sensors would help in finding positioning co-ordinates of hand movement. Briefly, in this paper we have proposed a system in which the mechanical arm imitates the gesture of the operator. The gesture data is collected through an Inertial Measurement Unit (IMU) which consists of a 3-axis gyroscope and accelerometer. A virtual reality head gear helps in viewing the workspace through a camera situated there. Among popular classification algorithms it is found out that Support Vector Machine (SVM) is proven to recognize gestures in less computation time with higher accuracy rate. The input to classifier is the data from IMU sensors and its output is the corresponding label which defines the action performed by the mechanical arm. The wearable and mechanical arm are connected to a computer wirelessly through Bluetooth. The machine learning algorithm can be run on the computer and the output of the algorithm will be passed to Raspberry Pi that controls mechanical arm.

II. Related Work

[1] Paweł Pławiak et al. This paper presents a system for quick and effective recognition of hand gestures based on data glove equipped with 10 sensors. Collected data was preprocessed using normalization and PCA analysis to test increase in classification sensitivity with reduction of data. They designed models using 3 machine learning algorithms based on Neural Network, Support Vector machine and K-nearest neighbors. Through results they found out that SVM gave highest accuracy rate (98.32%) as compared to PNN (97.23%) and KNN (97.36%).

[2] Md Ferdous Wahid et al. This paper presents use of Electromyography (EMG) sensors for capturing gesture data. Five machine learning algorithms such as K-nearest neighbor (KNN), Discriminant analysis (DA), Naive Bayes , Random Forest and Support Vector Machine (SVM) were used to classify 3 different hand gestures. SVM showed maximum accuracy (97.56%) in classification which was further improved by normalizing EMG features (98.73).

[3] Ananta Srisuphab et al. This paper presents the design of an automated tool to assist construction workers in the hand signal communicative channel. This system uses Myo sensors which is a combination of surface Electromyography (EMG) and Inertial Measurement Unit (IMU). The algorithm used for classification is Multi-Layer Neural Network. Daubechies wavelet transforms was used to analyze in frequency domain along with normalization and 10-fold cross validation was performed. The highest mean classification accuracy achieved was 88.176%.

[4] Granit Luzhnica et al. This paper presents a gesture based system that can be adopted for general-purpose control of and communication with computing systems that are currently performed via mouse or smart phone gestures. This system uses a sliding window approach for data processing and hence

suitable for stream data processing. A combination of linear discriminant analysis and logistic regression is used which resulted in an accuracy of over 98.5% on a continuous data stream scenario.

[5] Karush Suri et al. In this paper an improved approach for gesture classification is proposed using a Deep Neural Network for classification of six hand gestures corresponding to the signs used in the Indian sign language using signals from three IMU units. Principle component analysis (PCA) is used for dimensionality reduction and data is normalized. An accuracy of about 97.386% is observed.

[6] Huda Abualola et al. In this paper a glove based Gesture Recognition system is proposed that tracks hand movement using inertial sensors. The proposed glove is able to recognize American Sign language letters and communicate them for external displays on smart-phones. The algorithm used is based on linear discriminant analysis (LDA) which allows accurate and low complexity classification with improved clustering and reduced dimensionality.

[7] Fang-Ting Liu et al. This paper presents use of SVM and Inertial Measurement units for gesture recognition. For achieving higher classification accuracy feature extraction is applied using principal component analysis and linear discriminant analysis. Principal Component Analysis is an algorithm used for feature extraction which helps in improving gestures classification sensitivity and accuracy considerably. SVM is used with radial basis function (RBF) kernel and a non linear SVM called Gausian SVM which provides a more precise classification and can also add non-linearity . Kernels help in improving the classification sensitivity and accuracy considerably.

[8] E.Kiran Kumar et al. In this paper Convolutional Neural Network (CNN) is used in the recognition of 3D motion-captured sign language. The 3D information of each sign is interpreted using Joint Angular Displacement maps (JADM) which uses both angular measurements and joint distance maps (JDM) and encodes skeletal data into color texture images.

[9] Yande Li et al. This paper proposes a system based on hand gesture recognition and real time game control to run an android game named Fly Birds. Accelerometer and gyroscope in wrist band is used to collect hand gesture information and Kinect camera captures video information which is mainly used to mark the data during gesture recognition stage. Sliding window and DTW algorithm is used to detect gestures in real time game control.

[10] Mehmet Celalettin Ergene et al. In this paper it is explained how robot hand can learn via imitation using image processing based on Artificial Neural network. Features were extracted using image processing algorithms such as filtering and background subtraction. The success rate of network is 90.1%.

IV. PROPOSED SYSTEM

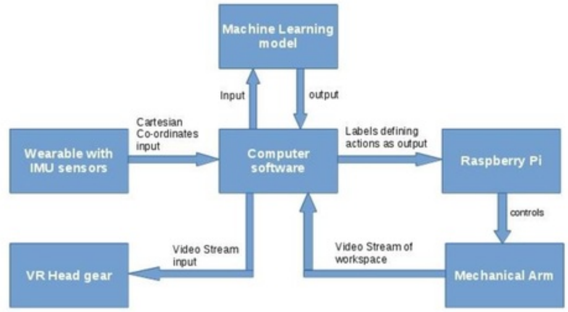

Fig 1: System Architecture

Wearable : The wearable consists of IMU sensors that get data of yaw, pitch and roll. It also consists a flex sensor that detects the bending of fingers. These data is send as input to the machine learning model.

VR Head Gear : A mobile consisting of VR app will be placed inside the head gear that will stream the live video of the workspace. The app would collect the sensor data from mobile to capture the orientation so that we can move the camera in workspace accordingly.

Linux Application : The linux application is responsible for running the machine learning model and handling the communication between wearable and mechanical arm. Linux application is made out of PyQT5 which is a Python interface for Qt, one of the most powerful, and popular cross-platform GUI library.

Machine Learning model : The model gets prepared after learning process using the data acquired from sensors. This machine learning model is used to predict the actions to be performed by the mechanical arm. The output of machine learning model is in the form of labels that are mapped to the type of action performed by mechanical arm. The output labels get mapped to the servo motor rotation angles of mechanical arm and accordingly each joint movement takes place. The algorithm used is Support Vector Machine (SVM) which is proved to be efficient and fast for classification with less number of features as compared to other models.

V. IMPLEMENTATION

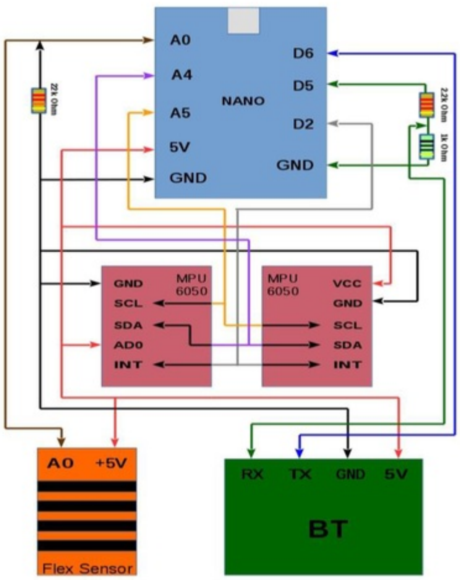

Fig 2 : Data Glove Schematic

For the implementation of the system we need to first setup all the hardware required in the system. The hardwares include wearable and mechanical arm. The figure 2 shows schematic diagram of the wearable glove. It consists of two MPU6050 IMU sensors , Arduino nano, Bluetooth module and a flex sensor. All the data from the flex sensor and IMU units are collected into Arduino nano which sends this data to our linux application via bluetooth.

M1-X	M1-Y	M1-Z	M2-X	M2-Y	M2-Z	F

Fig 3 : wearable glove output tuple

The Output of the wearable is a tuple with seven columns that are yaw, pitch and roll values of both IMU units as well as values of the flex sensor. This tuple is send as an input to machine learning model via bluetooth.

The machine learning model runs on a linux application. This application acts as the coordinator between the wearable and the mechanical arm. The application is made out of PyQT5 which is a Python interface for Qt, one of the most powerful, and popular cross-platform GUI library. It takes the tuples send by wearable as input and sends it to the machine learning model which predicts the output required to move the mechanical arm accordingly.

The machine learning model can be implemented using scikit learn library which is a python based library used for the implementation of various machine learning concepts. The algorithm used is Support Vector machine (SVM) along with kernel which introduces non-linearity. The input to the model is the tuple send by wearable and the outputs are the predicted classes. Each class corresponds to a specific action performed by mechanical arm which is in the form of servo motor angles. The correspondence of the classes and angels are recorded during the data collection phase. These servo motor angles are send to the raspberry pi which controls the mechanical arm. The mechanical arm has four servo motors that handles its movements. Its structure is as shown in figure 4. Each join has a servo motor named S1, S2, S3 and S4. It is controlled by a raspberry pi that sets the angles of servo motors for performing various actions.

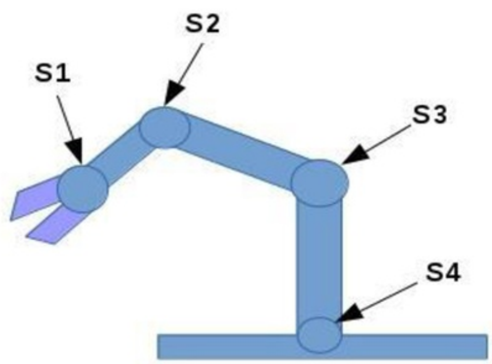

Fig 4 : Mechanical arm structure

A Virtual reality head gear is used which gives us a proper view of the workspace where the mechanical arm is kept. Inside the head gear an android mobile is inserted which runs a VR application. This application streams the live video of the workspace in a split screen format suitable for the head gear. The app also captures the accelerometer and gyroscope sensors data of the mobile which is used to control the movement of onsite camera according to the orientation of the users head.

VII. CONCLUSION

In this paper, we proposed a system for imitation of hand gestures by a mechanical arm which would help operate machines wirelessly from a distance easily so that we can operate machines that are used in hazardous places where . This provides a comfortable work environment for operator and the handling of machines with complex controls can be done easily through hand gestures. For wireless communication Bluetooth and Wi-Fi can be used .We have combined algorithms like SVM and PCA to design an effective machine learning model. This system can be further developed to perform computations over cloud and control machines through Internet if bluetooth or Wi-Fi connection is not possible.

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