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Home Automation and Wheelchair Control: A Survey

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Abstract: The technology has been successful in making our lives easy since its inception. Several devices and gadgets have been developed to serve both physically abled and challenged individuals. Billions of money is being invested in devices that can assist the paralysed in their daily chores – could be related to communication or movement or even controlling the electrical appliances in their homes. This paper summarises the recent advancements made in this regard and also draws a light on the shortcomings of these methods.

Keywords: Gesture; Flex Sensors; Kinect camera; Microcontroller; Home Automation; Wheelchair; Control; Paralysis

I. INTRODUCTION

Paralysis is a loss of muscle function in part of the body. It is when one cannot move certain parts of his/her body after something goes wrong with their connection to the brain. It comes in many different forms and could be either temporary or permanent [1]. Most of the times, this may not be due to problem with the muscles themselves. It is more likely due to a problem somewhere along the chain of nerve cells that run from the body part to the brain and back to that part again. These nerve cells deliver the signals of one's muscles to facilitate the desired movement. But when paralysis happens, desired movement cannot happen. Paralysis is often caused by strokes, usually from a blocked artery in your neck or brain. It can also be caused by damage to your brain or spinal cord, like what can happen in a car accident or sport injury. Almost, between 250 000 and 500 000 people in the world, suffer a spinal cord injury (SCI) every year [1]. There is no reliable estimate of global prevalence, but estimated annual global incidence is 40 to 80 cases per million population. Up to 90% of these cases are due to traumatic causes, though the proportion of non-traumatic spinal cord injury appears to be growing [1]. The different types of paralysis are Partial, complete, permanent, temporary, flaccid and spastic.

Paralysis can occur in any part of the body and is either localized, when it affects only one part of the body such as face, hands, feet, or vocal cords, or generalized, when it affects a wider area of the body. The type usually depends on where brain or spinal cord is injured. It is broken down based on how much of the body is paralyzed. Depending on the extent of how much paralysis has occurred it is categorized as Monoplegia, Diplegia, Hemiplegia, Quadriplegia or Tetraplegia and Paraplegia The rarest and most severe form of paralysis is locked-in syndrome, a condition in which a person loses control of all the muscles except the ones that control the eye movements.

In this paper, we have conducted a survey on recent papers that have developed systems for wheelchair motion as well as home appliances control. A summary of the same can be found in next section.

II. LITERATURE SURVEY

The below list (TABLE I) outline survey of papers related to the topic in brief with possible gaps/limitations within the proposed system.

Article	Description	Drawback
Hand Gesture Recognition in Real Time Using IR Sensor (2017) [2]	IR based motion sensors are attached to gloves. These gloves are to be worn and perform the gestures. These gestures are decoded by a microcontroller to perform a specific activity.	Strap on sensors can create inconvenience to the user. The unit is bulky.
Sign Language Recognition Using Wearable Electronics: Implementing k-Nearest Neighbors with Dynamic Time Warping and Convolutional Neutral Network Algorithms (2020) [3]	Flex sensors are used to obtain sensor data. The obtained data are analyzed using k-nearest neighbor's and CNN for machine learning.	Wearables can cause inconvenience to the users.
An Accelerometer Based Hand Gesture Recognition Digital Pen (2015) [4]	This paper uses a MEMS accelerometer sensor, which has to be stuck to the wrist/any finger while doing actions. The accelerometer records the movement of the hand in x, y and z axes. The obtained data is processed to map the motion of the hand.	Strap on sensors can create inconvenience to the user. The unit is bulky.
Hand gesture recognition in real world scenario using approximate string matching (2020) [5]	This paper proposes the use of a lean motion controller to detect the gestures. Fingertips are detected in this paper which can be used for several applications.	A readymade SDK development toolkit is used for developing the project, thus showcasing no novelty in the paper. Cost of the leap sensor varies from INR 6000 to 11000, which is extremely expensive.
Gesture recognition using a bioinspired learning architecture that integrates visual data with somatosensory data from stretchable sensors (2020) [6]	A stretchable strain sensor is developed which can fit easily on the skin. The data from this sensor is captured to analyze the somatosensory signals sent to the brain. The dataset obtained from the sensor is analyzed using BSV associated learning. Also, a camera is used to associate the visual information with the sensed data.	Flex/Strain sensors cost INR 500. But, since this is a fabricated sensor to ensure the thinness of the setup, the cost goes extremely high.
Dynamic Hand Gesture Recognition Based on a Leap Motion Controller and Two-Layer Bidirectional Recurrent Neutral Network (2020) [7]	This paper proposes the use of a lean motion controller to detect the gestures. Neural network is used to analyze the data to identify gestures in this paper.	A readymade SDK development toolkit is used for developing the project, thus showcasing no novelty in the paper. Cost of the leap sensor varies from INR 6000 to 11000, which is extremely expensive.
A Frame Detection Method for Real-Time Hand Gesture Recognition Systems Using CW-Radar (2020) [8]	Around the wrist, sensors are placed to find our wrist motion. The finger motion is performed in front of radars (similar to ultrasonic sensors) which detects the motion of the sensor. SVM classifiers are used to detect the gesture shown by analyzing the acquired data from the sensors.	Wearables can cause inconvenience to the users.
Gyroscope-Based Continuous Human Hand Gesture Recognition for Multi-Model Wearable Input Device for Human Machine Interaction (2019) [9]	This paper uses a MEMS accelerometer sensor, which has to be stuck to the wrist/any finger while doing actions. The accelerometer records the movement of the hand in x, y and z axes. The obtained data is processed to map the motion of the hand.	Strap on sensors can create inconvenience to the user. The unit is bulky.

Hand Gesture User Interface for Smart Devices Based on Mems (2016) [10]	This paper uses a MEMS accelerometer sensor, which has to be stuck to the wrist/any finger while doing actions. The accelerometer records the movement of the hand in x, y and z axes. The obtained data is processed to map the motion of the hand.	Strap on sensors can create inconvenience to the user. The unit is bulky.
Air Writing Gesture Recognition using Ultrasound Sensors and Grid-Eye Infrared Array Sensors (2019) [11]	Ultrasonic sensors are used to show gestures. The gesture shown here is position based, hence these sensors define the position of the finger/hand. Doppler's effect is utilized for gesture.	Any object placed in front of the sensor will be sensed as a finger, thus involving false identification of the gesture.
Hand Tracking and Gesture recognition using Lensless Smart Sensors (2018) [12]	A wearable setup is designed such that infrared LEDs can be placed on the setup. This setup is like a glove, which is 3d printed. Infrared sensors are used to track these LEDs, thus tracking the motion of the hand.	Wearables can cause inconvenience to the users.
A real-time gesture recognition system using near-infrared imagery (2019) [13]	A wearable setup is designed such that infrared LEDs can be placed on the setup. This setup is like a glove, which is 3d printed. Infrared sensors are used to track these LEDs, thus tracking the motion of the hand.	Wearables can cause inconvenience to the users.
Hand Gesture based Wheelchair Controller For the Disabled (2016) [14]	This paper uses a MEMS accelerometer sensor along with Ultrasonic sensor. Ultrasonic sensor will be placed in front of the wheel by which obstacles can be detected and they are programmed only to turn ON the buzzer.	Any object placed in front of the sensor will be sensed as a finger, thus involving false identification of the gesture.
Kinect Sensor-Based Long-Distance Hand Gesture Recognition and Fingertip Detection with Depth Information (2018) [15]	Kinect based solutions have ready SDKs to extract the edges from the object shown in front of the camera. Convex hull-based algorithms are used to detect how many fingers are open.	Kinect cameras are expensive. They cost around INR 6000 to 20000.
Micro Hand Gesture Recognition System Using Ultrasonic Active Sensing (2018) [16]	Ultrasonic sensors are used to show gestures. The gesture shown here is position based, hence these sensors define the position of the finger/hand. Doppler's effect is utilized for gesture.	Any object placed in front of the sensor will be sensed as a finger, thus involving false identification of the gesture.
Analysis of movement and gesture recognition using Leap Motion Controller (2018) [17]	This paper proposes the use of a lean motion controller to detect the gestures. Fingertips are detected in this paper which can be used for several applications.	A readymade SDK development toolkit is used for developing the project, thus showcasing no novelty in the paper. Cost of the leap sensor varies from INR 6000 to 11000, which is extremely expensive.
Gesture Recognition using Magic Ring Sensor (2016) [18]	This paper uses a MEMS accelerometer sensor as ring, which has to be stuck to any finger while doing actions. The accelerometer records the movement of the hand in	Strap on sensors can create inconvenience to the user. The unit is bulky.

	x, y and z axes. The obtained data is processed to map the motion of the finger.	
Gesture recognition using a bioinspired learning architecture that integrates visual data with somatosensory data from stretchable sensors (2020) [19]	A stretchable strain sensor is developed which can fit easily on the skin. The data from this sensor is captured to analyze the somatosensory signals sent to the brain. The dataset obtained from the sensor is analyzed using BSV associated learning. Also, a camera is used to associate the visual information with the sensed data.	Flex/Strain sensors cost INR 500. But, since this is a fabricated sensor to ensure the thinness of the setup, the cost goes extremely high.
CNN+RNN Depth and Skeleton based Dynamic Hand Gesture Recognition (2020) [20]	This paper creates a skeletal and depth mapping of the gesture shown using a normal camera using two machine learning algorithms - convolutional neural network (CNN) and recurrent neural network (RNN).	Extremely complex.
Gyroscope-Based Continuous Human Hand Gesture Recognition for Multi-Modal Wearable Input Device for Human Machine Interaction (2019) [21]	This paper uses a MEMS accelerometer sensor, which has to be stuck to the wrist/any finger while doing actions. The accelerometer records the movement of the hand in x, y and z axes. The obtained data is processed to map the motion of the hand.	Strap on sensors can create inconvenience to the user. The unit is bulky.
IoT Based Sign Language Interpretation System (2019) [22]	Data from flex sensors attached to gloves is acquired and analyzed to identify gesture.	Wearables can cause inconvenience to the users.
Hand Gesture Recognition Algorithm for Smart Cities based on Wireless Sensor (2017) [23]	The images of the gestures are captured using a camera. The gesture images are pre-processed and background removal is performed using background subtraction. Features called as image moments that calculate angles between fingers are obtained. Also edges of the gestures are found. Euclidean distances between these edges are found out to identify the gesture being shown. All the parameters are judged using a rule-based classifier to identify the gesture shown.	Background subtraction in real time fails to provide accurate results, especially in real-time implementation. One of the major concerns that can cause inaccurate results from background subtraction is change in brightness and contrast during the live mode.
Development of Real-Time Hand Gesture Recognition for TableTop Holographic Display Interaction Using Azure Kinect (2020) [24]	Kinect based solutions have ready SDKs to extract the edges from the object shown in front of the camera. Convex hull-based algorithms are used to detect how many fingers are open.	Kinect cameras are expensive. They cost around INR 6000 to 20000.
Multimodal hand gesture recognition using single IMU and acoustic measurements at wrist (2020) [25]	Accelerometer is placed on the posterior palm. Microphones are placed on the wrist. The acoustic signals picked up by microphones help to analyze the gestures such as taps and claps. The accelerometer	Wearables can cause inconvenience to the users.

	and gyroscope help to analyze the hand motion, thus decoding the gesture.	
Enhance Robotics ability in Hand Gesture Recognition by Using Leap Motion Controller (2017) [26]	This paper proposes the use of a lean motion controller to detect the gestures. Fingertips are detected in this paper which can be used for several applications.	A readymade SDK development toolkit is used for developing the project, thus showcasing no novelty in the paper. Cost of the leap sensor varies from INR 6000 to 11000, which is extremely expensive.

These hand gestures can be either moving the finger anywhere in the area or can be showing different signs by bending the fingers or moving the entire hand with gestures. These gestures can be either identified using sensors such as flex sensors and accelerometers or using camera [27-28]. More survey can be found in [29].

III. CONCLUSION

In some of the hand gesture recognition systems, the strap on sensors often created inconvenience the user and having a complex background, i.e., if any other objects in the scene were placed in front of the sensor, then that was being misinterpreted as finger, thus involving false identification of gesture. Moreover, wearables such as hand gloves also caused inconvenience to the user. Hence, in order to overcome these problems, we propose to design and develop an air gesture interface for wheelchair motion and home automation control. In this system, a dataset of images of different air gestures is created and an algorithm is developed to identify the gesture. If the gesture corresponds to wheelchair motion, the info is sent to motor controlling the wheelchair, while, if gesture corresponds to control home appliances, then home appliances are controlled via a Bluetooth interface.

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