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Hardware Interaction using Hand Gestures

K. A. Jain[1], P. Mishra[2], L. Arora[3], M.S. Kotian [4]

[1,2,3,4] Information Technology, Shri Ramdeobaba College of Engineering and Management, Nagpur, India

**Corresponding: khushboo.thakkar86@gmail.com*

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***Abstract*—**Gesture recognition is a mode for computers to begin to comprehend human body language, thus structuring a better-off channel between machines and humans than primitive text user interfaces or even GUIs. It enables humans to communicate with the machine and interact naturally without any intervention of mechanical devices. This technology not only saves time to unlock or operate any device but also makes human-computer interaction natural. The focus of this paper is on building a hand gesture recognition device using image processing for controlling the appliances by simple hand gestures instead of using any remote control devices or switches, thereby making user interaction as natural as possible. This is achieved by building a robotic arm using leap motion, Arduino UNO and different types of motors.

***Keywords*—**gesture recognition, image processing, leap motion, human-computer interaction.

I. INTRODUCTION

A. OVERVIEW

'Gesture Controlling' is the bustling word in robotics these days. People have always wanted to interact with natural and intuitive machines instead of the conventional ones. Because of this, gesture controlled machines are gaining popularity day by day.

In the general context of Human-Machine Interaction, new interfaces have been born. These provide a more natural interaction and a transparency of the computer tool. We cite, for example, the gestural interfaces, which propose to improve the Human-Machine Interaction (HMI) using the recognition of user gestures to enter commands. In this context, we hear a lot about the gestural controller “Leap Motion” (LM). It offers a virtual interface to overcome any physical contact between the man and the machine, specifically the computer. [1]

Two types of gestures are present in computer interfaces:

1. Offline gestures: These gestures are the ones that are processed post interaction of the user and the object.

2. Online gestures: These gestures process simultaneously with the user interaction which makes them term as direct manipulation gestures. They are used to scale or rotate a tangible object. [1]

Few advantages of gesture recognition are:

1. High accuracy
2. High stability
3. Saves time in operating a device

Despite the advantages of gesture controlling, the technology faces certain challenges. The main challenge is attaining accuracy of the gesture recognition software and the device. How well and how quick the sensor detects the gesture and responds correctly is critical.

The application of this technology lies in several sectors. It can be used in home automation by connecting the gesture recognition system to Wi-Fi. It could also be used to drive cars through gestures only. Reaching to virtual reality with bare hands through leap motion is a boom for gaming sector.

B. PROBLEM DEFINITION

Hardware devices can be operated using many parameters and these parameters are different for every device. Modern machines have many applications but controlling these machines is sometimes a very tedious job. For example, one of the modern day machines JCB have to be operated using multiple levers and joy-sticks. This requires a lot of precision and training.

In this project, we aim to build a unified control system that can be integrated in a hardware device and control the device using different gestures.

C. OBJECTIVE

To satisfy the above problem definition, we built a robotic arm and tried to control it using the leap motion device and hand gestures. So, the broad objective of this paper is to create a robotic arm that can replicate the gestures of the human arm.

Through this paper, we intend to explain how the robotic arm is controlled using the leap motion device and hand gestures. We also explain how a leap motion device works along with Arduino UNO.

Rest of the paper is organized as follows, Section I contains the introduction of gesture recognition technology along with our problem definition and objective behind writing this paper. Section II gives a brief summary of few of the published papers in the same field, referred by us during the development of our project. Section III contain details of the hardware and software used in order to achieve the objective. Section IV explains the methodology adopted in order to achieve the desired objective, Section V illustrates the results achieved. and Section VI concludes research work with future directions.

II. Related Work

A study by Dr. B.L.Malleswari, Dr. B.K.Madhavi depicts a new approach for hand tracking and gesture recognition based on the Leap motion device. They talked about a system which processes the depth image information and the electrical activity produced by skeletal muscles on forearm. The purpose of such combination is enhancement in the gesture recognition rate. [2]

Another study by Safa Ameur Anouar Ben Khalifa depicts an interactive application with gestural hand control using leap motion for medical visualization, focusing on the satisfaction of the user as an important component in the composition of a new specific database. [3]

"Intelligent hardware multimodal interaction design" by Jiuqiang Fu Bing Jiang Xin Yang writes about a reasonable way of intelligent hardware interaction design by intelligent hardware prototype design and evaluation and summarizes the principle of multi model interaction. [4]

Summary of all the papers we referred for the development of our project is depicted in the table 1.

Table 1. List of papers studied

TITLE AND AUTHOR	OBJECTIVE	CONCLUSION
Bomb defusing robot controlled by gestures with Arduino and Leap Motion *By* Dr. B. L. Malleswari Dr. B. K. Madhavi (2016)	Developing a robot that can be controlled by gestures using a Leap Motion Device that can sense human hands and keeps a track of them in order to aid in navigation.	This paper that still has some work in progress illustrates an existing robot that is designed by them, which can be controlled by hand gestures.
A comprehensive leap motion database for hand gesture recognition *By* Safa Ameur Anouar Ben Khalifa (2017)	To present an interactive application with gestural hand control using leap motion for medical visualization.	In this paper, the authors proposed a 3D dynamic gesture recognition approach explicitly targeted to leap motion data.
Hand gesture recognition based on shape parameters *By* Meenakshi Panwar (2012)	To present a real time system for hand gesture recognition based on features like orientation, centre of mass (centroid), status of fingers, thumb and their respective location in image.	The algorithm proposed in this paper has been tested over 450 images and gives approximately 94% of the recognition rate.
Intelligent hardware multimodal interaction design *By* Jiuqiang Fu Bing Jiang Xin Yang (2016)	The research paper explores the reasonable way in which an intelligent hardware interaction can be designed and evaluated	The conclusion states that the multimodal interaction design can effectively improve the efficiency of the use of the intelligent hardware.

III. HARDWARE

To satisfy our problem statement, we tried to control the intensity of an LED using hand gestures. Further, we also built a robotic arm that could be controlled using hand gestures.
In order to achieve the above mentioned objectives the hardware and software required are given below:

1. Leap Motion:
It is a hardware device that enables us to control using natural user interface based on gestures. At the heart of the device, there are three infrared LEDs and two cameras. The USB Controller of the device reads the data collected by the sensor into its local memory and adjusts the resolution if necessary. This is then streamed through the USB to the Leap Motion tracking software. The data is in the form of a grey-scale stereo image of the near-infrared light spectrum that is separated into the two cameras on the right and left. The workspace of this controller is eight cubic feet. This interaction space takes the form of an inverted pyramid which is the intersection of the binocular camera's field of view.

Compared to the Microsoft Kinect sensor, which, due to a distance of less than one metre between the sensor and the user, is unstable in terms of gesture recognition, the new Leap Motion sensor is much more efficient owing to its new hardware system. By contrast to the sensor accuracy of the Microsoft Kinect, Leap Motion's sensor precision is of the sub-millimetre order, as specified in the Leap Motion documentation - more precisely, 0.01 mm [5] The viewing range of the leap motion controller is limited to 2.6 feet (80 cm). The range is limited as it becomes difficult to deduce the position of hands in three dimension beyond a certain distance.

The most recent version of leap motion's SDK is Orion Version 3.1.2. The properties of a frame object in the Orion version are listed below:

- Palm position P_{pos} , normal P_N and velocity P_v.
- Hand direction P_D.
- Fingertips position F^i_{pos}, direction F^i_D and velocity F^i_v where i starts from 0 to 4 representing thumb, index, middle, ring and little respectively.
- Arm direction [6]

Programming languages that are supported by leap motion controller are C++, Objective-C, C#, Java, Python, JavaScript. Other languages can be used by data binding. The device supports OS X 10.6+ и Windows 7+ operating systems. An experimental version for Linux subsists only for developers. [7]

2. Arduino UNO:
Arduino is an open source physical computing platform used to develop stand-alone devices or to connect to a software in your personal computer. It is a ATmega328P board based microcontroller that has 14 digital input/output pins, 6 analog inputs, a 16 MHz ceramic resonator, a USB connection, a power jack, an ICSP header and a reset button.

6 of the 14 pins can be used as Pulse Width Modulation outputs, i.e., for simulating analog output. 6 analog inputs for reading values from components like a potentiometer or an LDR. It is connected to the host computer through a USB type A to USB type B cable, which can also power the board. It also has a power jack if components attached need more voltage or current, an ICSP header for expansion and a reset button to reboot the board instantly. The ATmega328 has 32 KB. It also has a 2 KB of SRAM and 1 KB of EEPROM. [8]

3. Servo Motors(SG90):
It is a rotary actuator or motor for precise control in terms of the angular position, acceleration and velocity. Thus, it has capabilities that a regular motor does not have. It uses a regular motor along with a sensor for position feedback. They are tiny and light weight. This servo can rotate approximately 180 degrees (90 degrees in each direction), and works just like the standard kinds but smaller in size. It comes with a 3 horns (arms).

4. DC Motor:
Direct Current(DC) motors converts DC electrical energy to mechanical energy. They work on the principal, when a current carrying conductor is placed in a magnetic field, it experiences a torque and has a tendency to move. This is known as motoring action. If the direction of current in the wire is reversed, the direction of rotation also reverses. When magnetic field and electric field interact they produce a mechanical force, and based on this working principle, DC motor is established.
We have used 6V, 180rpm Micro DC Geared Motor with Shaft to move the robotic arm. These motors are inexpensive, small, easy to install, and ideally suited for use in a mobile robot car.

5. L298n Motor Driver:
The Motor Shield is based on the L298, which is a dual full-bridge driver designed to drive inductive loads such as DC, relays and stepping motors. It allows you to drive two DC motors, controlling the speed and direction of each one independently.

IV. METHODOLOGY

The workflow of this project is illustrated in the figure 1.

We decided upon three gestures that did not involve crisscrossing of fingers for our robotic arm. The gestures are:

1. Grab (opening and closing of palm)
2. Yaw (translation of hand in x-z plane)
3. Lift (translation of hand in y-z plane)

Figure 1. Flowchart for controlling a robotic arm using leap motion

Grab

The purpose of the grab function is to enable the robotic hand to grab a variety of objects. We set a maximum limit of weight that the hand would lift to protect it from any physical damage. We made sure that the hand applies enough normal force on an object (tested for 200g) without slithering.

The software implementation of this functionality is done through Processing IDE that provides predefined libraries for leap motion. A predefined float grabAngle() is used to capture the angle between the fingers and the palm of the grab hand pose. The angle is computed using the angle between direction of the 4 fingers and direction of the hand. Thumb is not considered when the angle is computed. The angle is 0 radians for a hand that is open, and reaches pi radians when the pose is a tight fist.

Yaw

Yaw is basically the horizontal movement performed by the robotic arm. In this the load is precisely on the axel of the motor. Servo motors motion are aligned parallel to x-z plane and a moment of 170 degrees is gained.

Again, the software implementation of this functionality is provided by Processing IDE. The predefined function used here is float yaw(). Yaw is the angle between the negative z-axis and the projection of the vector onto the x-z plane. In short, yaw represents rotation around the y-axis and is measured in radians. If the vector is pointed at right of the negative z-axis, then the angle that is returned is between 0 and pi radians (180 degrees); if it is pointed to the left, the angle is between 0 and - pi radians.

Lift

Two adjacent servo motors are used by the robotic arm to implement the lift motion as it requires a lot of power. The motors are aligned parallel to y-z plane and are synced to work at the same time. They rotate in same directions at same degrees per second. We were able to gain a moment of approximately 90 degrees. The weight that the robotic arm can lift depends upon the distance between the object and the axel servo motor. For instance, for a distance of 1cm the servo motor can lift 1.2kg weight. If the distance is 10cm the servo motor can lift 0.12kg weight.

V. RESULT

We designed and developed a robotic arm capable of performing the discussed hand gestures along with lifting and moving light weight objects, shown in the following figures:

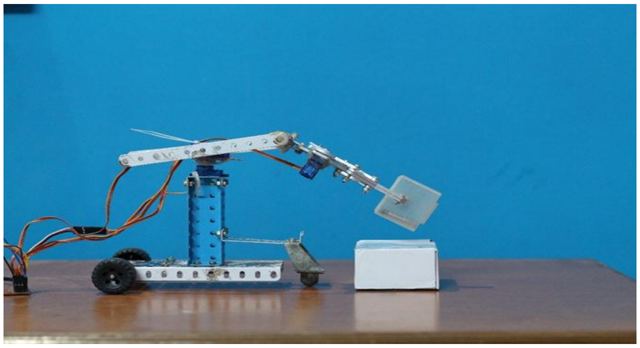

Figure 2. Robotic arm performing grab gesture

Figure 2 shows a robotic arm grabbing an object corresponding to a human hand grab gesture.

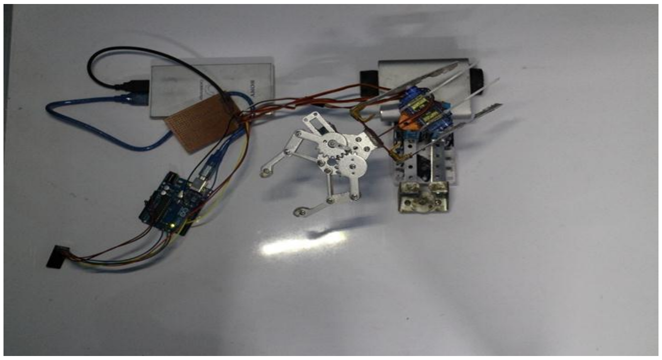

Figure 3. Robotic arm moving right

In figure 2, the robotic arm moves right corresponding to a human hand moving right.

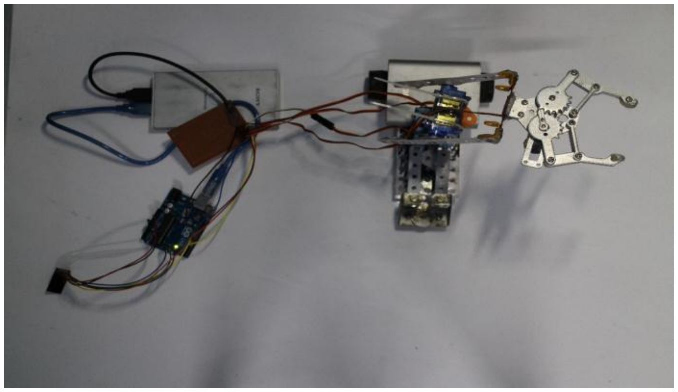

Figure 4. Robotic arm moving left

In figure 3, the arm now moves left from its previous position corresponding to a human hand moving left.

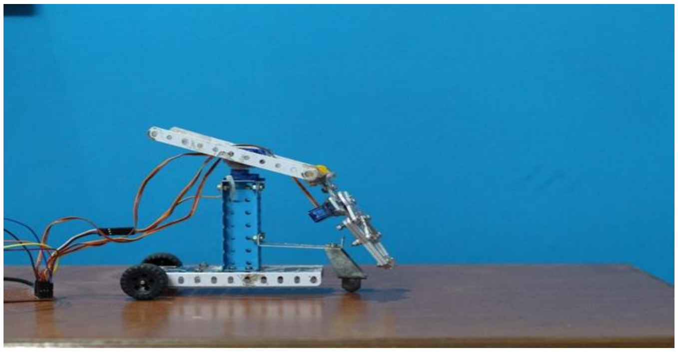

Figure 5. Robotic arm moving down

In figure 4, the robotic arm moves down corresponding to a human hand moving down.

In figure 5, the robotic arm moves up corresponding to a human hand moving up.

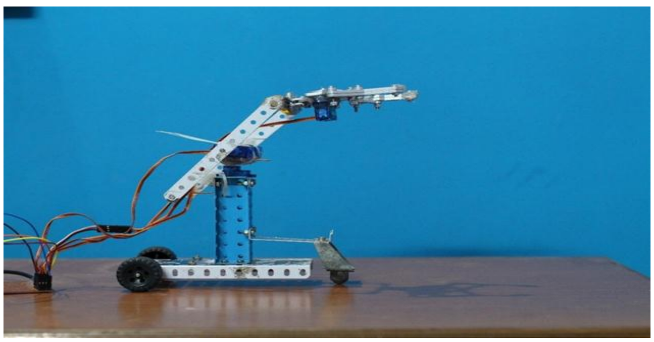

Figure 6. Robotic arm moving up.

VI. CONCLUSION AND SCOPE

This paper basically talks about a way of making user-hardware interaction as natural as possible using gesture recognition technology with leap motion. Our motivation for developing this robotic arm was the rise of using gesture control mode in the field of robotics. Though, we programmed this arm for only few basic gestures, but if developed further with no time lag and higher accuracy, it can be used in medical field to perform surgeries and in military applications. One of its major application could be in the research field where it could be used to reach places which are not human friendly.

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Authors' Profile

Mrs. Khushboo Jain currently works as an Assistant Professor in Shri Ramdeobaba College of Engineering and Management, Nagpur, Maharashtra. She pursed M.Tech in Computer Science and Engineering and Bachelor of Engineering in Information Technology. She has a teaching experience of more than 6 years. Her area of interests are Natural Language Processing and Automation.

Ms. Lovely Arora will complete her Bachelor of Engineering in Information Technology in June, 2018 from Shri Ramdeobaba College of Engineering and Management, Nagpur, Maharashtra.

Ms. Mayuri Kotian will complete her Bachelor of Engineering in Information Technology in June, 2018 from Shri Ramdeobaba College of Engineering and Management, Nagpur, Maharashtra.

Mr. Prajwal Mishra will complete her Bachelor of Engineering in Information Technology in June, 2018 from Shri Ramdeobaba College of Engineering and Management, Nagpur, Maharashtra. He is also a freelancing graphic designer.

