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A Study on Gesture Controlled Robotics Arms and Their Various Implementations

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***Abstract* - Robots today are dexterous, capable of performing incredible feats of engineering and displaying human like qualities. Robotics presents vast potential in every domain and is rapidly emerging as a game changer. This paper analyses the various system designs of robotic arms wherein the user controls the position of the joints. Various means of control are explored, namely external hardware modules, smartphone applications and IoT based control. A comparison between the various methodologies has been made and the possible advantages and disadvantages have been listed. This paper seeks to survey existing implementations and to highlight potential areas of research and development.**

Keywords: Robotic Arm, Gesture Recognition, Long Range Navigation, Android OS, Bluetooth, IoT, Remote Access, Smartphone application.

I. INTRODUCTION

Robots have become an integral part of several industries and are set to become the backbone of many more. Through vigorous research, the field of robotics has been growing at a rapid pace. The versatile and flexible nature makes robots the best choice for an array of applications in fields like medicine, interstellar exploration, and military-grade systems. Since the advent of robotics, precise methods of control and integration with existing technology have been the subject of extensive study. In this paper, we have reviewed some of the methods to efficiently and easily control a robotic arm from a remote location. We have focused on three methods of control; each with its own set of advantages and disadvantages, extent of usage, and range of applications components used to put together the entire robotic arm along with its method of control. The controllers that have been studied are the Leap Motion Controller and the Microsoft Kinect Controller. They both fundamentally work on the basis of 'gesture recognition', We have discussed the literature survey done to develop this paper. It includes the main parameters and components used to put together the entire robotic arm along with its method of control. The controllers that have been studied are the Leap motion controller and the Microsoft Kinect Controller. They both fundamentally work on the basis of 'gesture recognition', which is a popular concept that is being vastly used in many embedded system technologies today. The Kinect being one of the oldest gesture recognition technologies used forms the basis to truly understand the concept. Recently, it has been replaced by newer and more viable alternatives such as the Leap Motion Controller. We have explored the structure, methodology and basic working of these controllers and have also brought out the differences between the two controllers on the basis of – complexity of use, architecture, processor and accuracy. The embedded control boards reviewed are Arduino, Raspberry Pi and the Odroid XU4. The Odroid-XU4 Graphics Controller coupled with Xilinx ZedBoard (Robotic Arm Controller) has been studied in great detail as it is a more advance embedded set up and was recently introduced to the robotic industry. The working of the Odroid XU4 has been discussed in detail alongside Arduino and the R-Pi which is two of the most commonly used control boards in the technology world. They have been compared on the basis of CPU cores, processor architecture, speed and RAM memory. By understanding the key features and specifications of each, their implementation and appropriate field of application is made clear, thereby facilitating further study and usage. Furthermore, we have vividly explained IOT and Smartphone application approaches to controlling the arm. The process involves interfacing the source of input, the controller board and the arm with each other under the required specifications. It also includes creating the appropriate platform to feed input; be it a mobile app or a web app. This serves as an effective method to control the robot from a remote location.

II. LITERATURE SURVEY

The robotic arm has found numerous applications in an array of industries. They are designed in manner so as to

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ensure maximum flexibility and usability for its planned application.

2.1 Controller Based Implementation

Gesture recognition is a strictly non-invasive approach to apply the user input for a wide range of actions. Gesture recognition and mimicry is an efficient method to be used in situations that pose a threat to humans, such as radioactive environments, bomb defusing missions, curtailing epidemics etc.

2.1.1 The Microsoft Kinect sensor

The Kinect sensor is used as an input device. It captures the motion of the human arm in real time and transfers the data to the processing unit. The Kinect sensor is used for the multiple features it grants the user, particularly the integration of the depth data and natural user interface, which allows both precise and versatile interaction with the user. The functioning of the Kinect based gesture control robotic arm necessitates the computation of the angles formed by the various links (vectors) and the joints.[2] Mechanically, there exist a number of joints and links spread throughout the robotic arm. The Links and the Joints constitute a co-ordinate frame. (Controller)

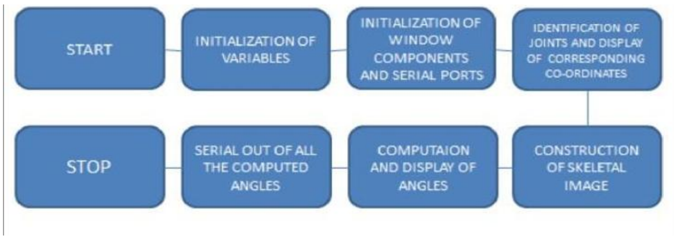

Figure 1: Kinect Programming Algorithm

The Kinect sensor has been used in numerous robotics projects along with Arduino due toits ability to interpret gestures using a standard video camera, a depth camera, and by projecting an infrared laser grid onto surfaces and creating information by scanning the distortions in the digital mesh. The same 3D sensor is used for voice command recognition, a feature that can be used together with the gesture interpretation or just for voice controls. The flexibility of the sensor makes it a good choice for gesture control and mimicry. [3]

The Odroid-XU4 Graphics Controller coupled with Xilinx ZedBoard (Robotic Arm Controller).

The ZedBoard is based on the Xilinx Zynq-7000 Extensible processing platform. It has anARM-Cortex-A9 processor along with 85,000 series-7 programmable logic cells to create unique designs. This board is used to control the servomotors attached to the robotic arm in a parallel manner instead of using concurrent architectures.[4]The Odroid-XU4 is a dedicated single-board computer used for Hand Gesture Recognition. It is a high performance and energy-efficient hardware.[4]

Table 1: Xilinx zed board specifications

Parameter	*Value*
SoC	Zynq-7000 All Programmable SoC XC7Z020-CLG484-1
Display	Multiple displays (1080p HDMI, 8-bit VGA, 128 x 32 OLED)
Memory	512 MB DDR3
Storage slot	4 GB SD card
USB	USB Adapter: Male Micro-B to Female Standard-A
Programming	Onboard USB-JTAG Programming
Expansion	PS & PL I/O expansion (FMC, Pmod™, XADC)
Ethernet	10/100/1000 Ethernet
DC Input	12 AC/DC power supply

Table 2: Table 2 Odroid-Xu4 Specifications

Parameter	*Value*
Processors	Samsung Exynos5422 Cortex™-A15 2Ghz and Cortex™-A7 Octa core CPUs
Graphics	Mali-T628 MP6(OpenGL ES 3.0/2.0/1.1 and OpenCL 1.1 Full profile)
Memory	2Gbyte LPDDR3 RAM PoP stacked
Storage slot	Micro-SD slot, eMMC 5.0 module connector
USB	2 x USB 3.0 Host, 1 x USB 2.0 Host
IO Ports	USB 3.0 Host x 2, USB 2.0 Host x 1, PWM for Cooler Fan, UART for serial console Ethernet RJ-45, 30Pin : GPIO/IRQ/SPI/ADC, 12Pin : GPIO/I2S/I2C
HDMI connector	Standard Type-A HDMI, supports up to 1920 x 1080 resolution
DC Input	5V / 4A input, Plug specification is inner diameter 2.1mm and outer diameter 5.5mm

Hand gestures are recognized using Odroid-XU4 using machine vision algorithms. The ZedBoard reads the values from the Odroid XU4 and the robotic arm performs the particular action based on the gesture input. Each gesture input activates the necessary servomotors and gives a specific position to the robotic arm. [4]

2.1.2 The Leap Motion Controller

The Leap Motion Sensor consists of two monochrome cameras with three infrared LEDs that generate a 3D dot pattern thereby enabling 200 frames per second of data. The data processing is performed by the SDK provided by the company. The leap Motion software detects movement of the hand and fingers translating the positions in 3D. The software analyzes the movement, considering the previous frame and current frame. The software considers the following information and data as variables: number of hands and

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fingers, position of each hand and finger, hand angle and palm speed. [7][8]

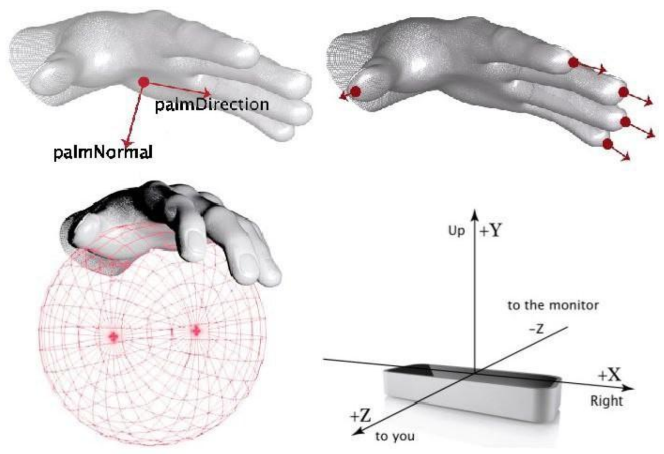

Figure 2: Axis system on leap motion sensor

The inclusion of a control strategy using the Leap Motion controller, based on gesture recognition enhances the relationship with the user-robotic arm interface. [9]

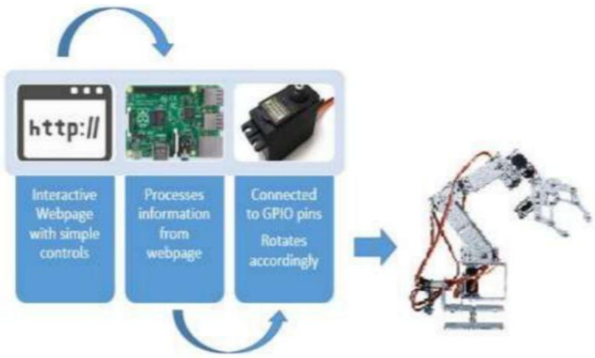

Figure 3: Block Schematic

2.2 Mobile App Based Implementation

Smartphones have the ability to support applications that can be used for various purposes, including control of robotic devices that work within a limited distance. Using a Bluetooth module or Wi-Fi module for shorter and longer distances respectively can control the range of the line of sight. The transmitter consists of an Android cell phone that has a Bluetooth chip. The data to control the robot will be transmitted through the cell phone. [10][11] An app is developed using various platforms like Android Studio, Eclipse or templates based on the necessary requirements of the end product. [12][13] There is a Bluetooth module at the receiver end. Once the Bluetooth devices are paired with each other the microcontroller compares the incoming data with the pre stored data and together with the Bluetooth module and acts as an interface to receive commands from the user – made app and consequently instructs the servomotors on the robot to perform accordingly. [14]

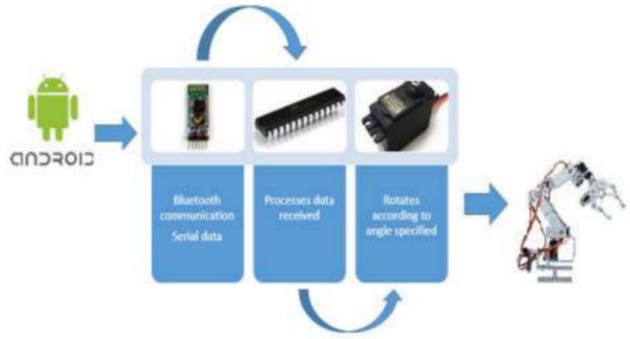

Figure 4: System architecture

2.3 IoT Based Implementation

By using the internet to gather data and access control over robotic gadgets that may be present at remote locations, we adopt a new concept called Internet of Robotic Things (IoRT). It includes the many ways by which IoT technologies and robotic devices transect to provide cutting-edge robotic capabilities. [15] The process begins with commands commencing at the user's web page or web app, based on the requirements of the end product. This is made via a web server, who's main objective is to deliver content to the client via the internet. It requires HTTP or Hyper Text Transfer Protocol helps in the communication between client and server. Pages delivered are HTML documents, which is standard markup language for creating web pages and web applications. [16] To improve the security, the web page must be locked with and ID and password. The inputs are then passed onto a microprocessor; among which the most used is the Raspberry Pi at present. It acts as an interface and further navigates the commands to the servomotors. Standard RCA exit can also be used as a display for Pi. R-Pi collects data and stores it in a database, which can be analyzed to see the image acquisition and precision movement of the robot arm. Applications that are developed using the hardware and software functions are combined to create a reliable system.

III. METHODOLOGY

3.1 Controller based implementation

Table 3: Comparison of Devices Used for Gesture Recognition[10] Device

Device	Leap motion sensor	Microsoft kinect
		
Complexity of Use	Easy	Easy
Architecture	3 Infrared LEDs 2 Monochrome cameras	RGB and Infrared Cameras Audio

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Processor	MXIC MX25L3206E	XCPU Xenon Xbox360
Accuracy	High	Medium

Table 4: Comparison of embedded controller boards [10]

Embedded board	Raspberry-pi	Arduino	Odroid xu4
			
CPU Cores	1	1	4
Processor Architecture	Bradcom ARM11	Atmega328	Samsung Exynos ARM Cortex-A15
Speed	700MHz	16MHz	2GHz
RAM Memory	256Mb	32kb	2Gb

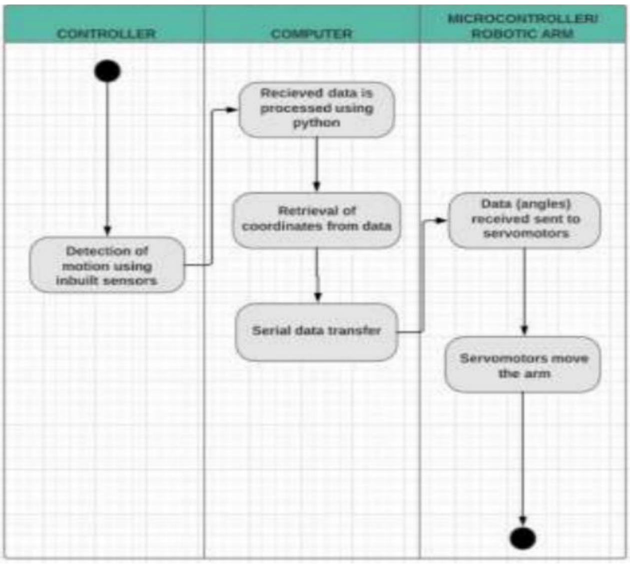


Figure 5: Controller Based Implementation

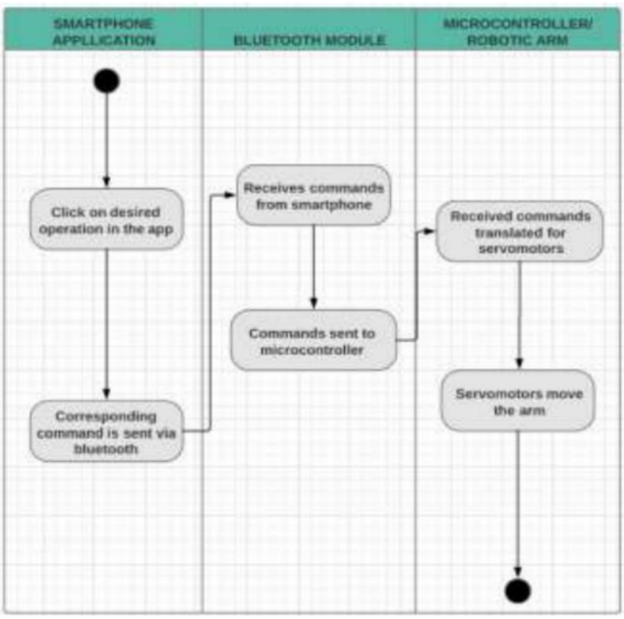


Figure 6: Mobile App Based Implementation

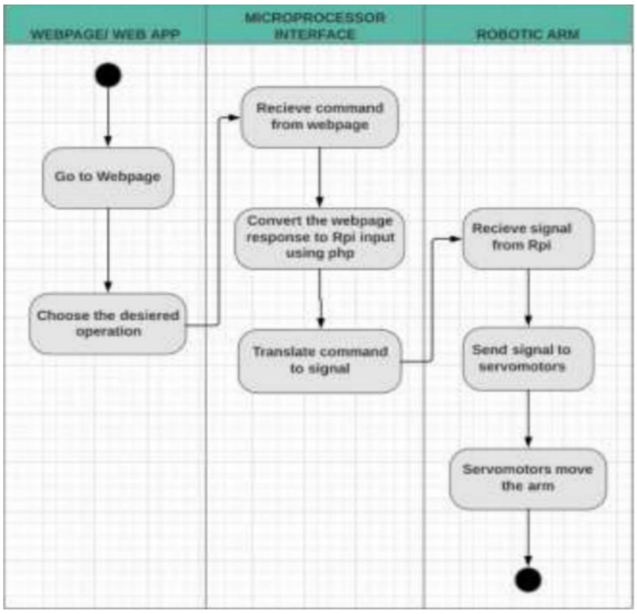
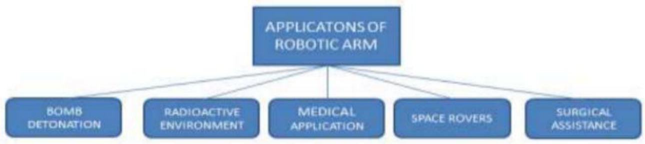


Figure 7: IOT Based Implementation

IV. APPLICATIONS

Bomb Detonation: Robots allow the close examination of devices, without endangering people. Once the device has been examined, the robot may then render the bomb inert. If not, errors can be avoided by using the robot itself to detonate the bomb and safeguard human life. It is not just bombs that the robots disable, but also devices that could detonate landmines or unexploded munitions.



Radioactive Environment: When dealing with radioactive materials, robots can be used to keep humans safe from genetic mutations and fatal diseases that may occur from radiations. They can be used in labs, nuclear power plants or in areas that have been damaged by nuclear energy. There are different types of robots that are used in areas of different kinds of radiations - alpha, beta and gamma. Robots with properly automated controllers can also be used to control nuclear power plants and hence can be used to avert nuclear power plant disasters like one that occurred at Chernobyl. Robots can also be used for the disposal of radioactive waste.

Medical application: Robot-mediated health care has paved the way for safe and hygienic medicine. Robots play an integral role in the battle against infectious diseases as they have the capability to disinfect a room of any bacteria and viruses within minutes. Robots, unlike humans, cannot catch infectious diseases. They are agnostic to specific infectious

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agents and do not contribute to medically-resistant strains. With the rise in antibiotic-resistant bacteria and outbreaks of deadly infections like Ebola, more healthcare facilities are using robots to clean and disinfect surfaces.

Space Rovers: Robots are the latest intelligent systems that have helped us with outer space exploration. Robotic unmanned space craft's are used to perform multiple functions in the extra –terrestrial world; including object recognition, image evaluation and terrain modeling. They involve AI-based methods for autonomous navigation and mission planning in unknown terrain and AI-based support systems for scientific experiments. The most famous robots used in the outer space applications are the Mars rovers of NASA.

Surgical Assistance and Rehabilitation Systems: Robots today have the abilities to assist surgeons with performing complex operations, typically minimally invasive procedures to avoid infections and outbreaks. 3DHD technology provides surgeons with enhanced natural stereo visualization, along with improved reality. Robotic links also play a crucial role in the speedy recovery of patients with disabilities, including improved mobility, strength, coordination, and overall quality of life.

V. FUTURE WORKS

There are some prospects for future work based on the context of the paper. Devising an exclusive method to make the serial transmission between the arm and the controller entirely wireless will augment the mobility of the system. Gesture recognition can be improved by using controllers that provide depth information in addition to mapping coordinates. To extend the range of mobile applications WIFI modules can be used instead of a Bluetooth module, thereby granting remote access. IoT based methodologies can be simplified by implementing them in environments that utilize web sockets, making the communication between the user and server more interactive.

VI. CONCLUSION

The possibilities and capabilities of Robotics are endless. The major advantage of utilizing robots is their dexterity, efficiency and precision. This paper studies the different approaches that can be taken in order to control a robot. For high accuracy usage such as applications in the medical field, hardware modules like the Leap Motion Controller are a more viable option due to the extent of controllability afforded. Smartphone applications and IoT based methods are ideal for low budget implementations and are versatile and flexible in their usage. They are easily customizable and readily available for use, the range of control can be modified based on the requirements. Thus, the three methods of control surveyed in this paper all have key features that distinguish them and make them good choices for controlling robotic arms.

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