IoT-enabled Gesture-Controlled Robotic Arm for Enhanced Industrial Automation

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Abstract- Robotics is a constantly evolving field nowadays. Several robots have been created to perform risky tasks that are impossible for humans to perform directly. The robot arm is one of the most popular types. In this project, it is proposed to control a robot arm using finger and hand movements. However, the traditional way of gesture control employs sensor-based gloves to track motion, which is time and energy intensive due to its weight. To overcome this problem, using vision for motion tracking can be the most suited method at hand currently. The ML based computer vision method provides us with the real-time landmark on different points of the hand. With these landmarks we can calculate various mathematical parameters that can be used for the control of the robot arm. Movements that are landmarked, are processed and formulated using the mathematical parameters. The final output of mathematical parameters fed to the microcontroller. Signals from the microcontroller will be the desired input signal to the motors. The rotation of the robot arm is controlled using movement of the human arm.

Keywords— IoT, Gesture Control, Robotic Arm, Industrial Automation, Human-Machine Interaction, Real-time Communication, Machine Learning, Computer Vision, Scalable Automation (key words)

1. INTRODUCTION

The integration of the Internet of Things (IoT) has transformed industrial processes, enabling seamless communication and data exchange among interconnected devices. Industrial automation has seen unprecedented advancements with the incorporation of IoT technologies. Our project aims to push the boundaries of industrial automation by integrating IoT capabilities with a robotic arm. The focus is on leveraging gesture control as an innovative and intuitive method for human-machine interaction. Our project proposes a solution through the novel integration of gesture control and IoT technologies.

I. RELATEDWORK

A lot of researches have been conducted in the area related to Gesture Based Robot Arm Control Poltak Sihombing et al. focus on the robot arm controlling is based on the movement of fingers and hands. The research work is aimed at the brief description of control of a simple robot arm by movement of human fingers and human hand. This project has created a robot arm using a Fuzzy logic technique to control the movement of robot arm. Yanmin Zhuet al. focus in using basic background subtraction, skin color detection, hand reach detection, palm detection. The detection of a complete palm is used to determine whether the hand extends beyond the camera's range of vision. The ergonomics idea is used to assess if the hand is outside of the camera's field of view. There has also been some more study done in this area. Using RGB cameras, Pramod Kumar et al. investigated numeric and subjective comparisons of algorithms and approaches. A collection of 13 metrics developed from various algorithm attributes and the experimental methodologies used in algorithm assessment are utilized to evaluate algorithms quantitatively. The project emphasizes the need of taking these factors into account, as well as the algorithm's identification accuracy,when predicting its success in real-world applications. Sakshi Sharma et al. described how he used accelerometers to control 5 servo motors with gestures. The use of an accelerometer to drive a robot arm is explored and implemented in the hardware.

II. SYSTEM COMPONENTS

In recent years, technology has provided various sources of basic items that assist people in meeting their requirements. As a result, the software's and algorithms assist developers in using the package, which is either an open-source platform or a commercial product, to build their own goods, which is helpful for various industries. Such software's and algorithms will be updated periodically to make a better component. The following components and software are used in this project. They are Arduino Mega, Servo motors, Battery, MediaPipe –Library.

A. MediaPipe

Recognizing the motion and formof hands could enhance the user experience in a wide range of technical areas and interfaces. In augmented reality, it enables the texture of digital material and information on top of the real world, as well as the interpretation of sign language and the control of hand movements. Because palms frequently entirely cover themselves or one another (for instance, hand occlusions and hand shaking), and there are no high contrast styles, hand perception in real time is a particularly difficult computer vision task.

MediaPipe's Hands is a high-resolution tracking device for hands and fingers. 21 3-dimensional landmarks of a hand are determined using machinelearning. A single image is used to determine 21 3D landmarks of a hand using machine learning. While most current framework systems rely on complex desktop environments for inference, our approach works in real time on a cell phone and can be scaled to many hands. By making these hand recognition.

B. Arduino Mega The Arduino Mega, built upon the ATmega2560 microcontroller, is an integral component within the Arduino platform, extending the capabilities established by the Arduino Uno. Developed by Arduino.cc, this microcontroller board is designed to provide enhanced flexibility and increased interfacing options for complex electronic projects. Distinguishing itself with 54 digital I/O pins (15 of which support PWM output) and 16 analog input pins, the Arduino Mega surpasses the Arduino Uno in terms of connectivity options. This expanded array of I/O pins makes the Arduino Mega an optimal choice for projects necessitating numerous sensors, actuators, or communication interfaces. The ATmega2560 microcontroller, crafted by Arduino.cc, upholds the standard of excellence set by Arduino Uno, ensuring reliability and compatibility across diverse applications. Similar to its counterpart, the Arduino Mega can be powered via a 9 V battery or a USB connection, offering versatile options for diverse project requirements. With a voltage handling capacity ranging from 7 to 20 volts, the Arduino Mega stands as a formidable tool for professionals and enthusiasts engaged in sophisticated and large-scale electronic projects.

Fig. 1. Arduino MEGA

C. Servo Motors

A servo motor is a rotary actuator that enables accurate angular position control. A motor and a position feedback sensor are used in it. To complete the system, a servo drive is necessary. The feedback sensor is used by the drive to accurately regulate the motor's rotational position. Fig. 2 depicts a DC Servo motor. Fig. 2. Servo Motor (DC)

Fig. 2. Servo Motor (DC)

D. Power Supply

A power supply is an electrical device that stores and transmits electrical energy in order to convert it into a various form of energy. A power supply or battery delivers the necessary electric energy to power the load at the needed voltage, current, and frequency.

Fig. 3. 5 V 1500 mAh Battery

III. METHODOLOGY

A systematic methodology is used with the ultimate goal of creating a fully functional human following load carrier in mind. This project takes a top-down, decentralized approach. There are numerous stages to the project. Step-by-step procedures were followed, starting with various literature surveys and then questioning about their concerns. After determining the most common issues, the problem statement was written. A solution was suggested for the aforementioned issues, and the best solution was chosen. The main concept for the design has been chosen, and numerous existing publications and patents have been evaluated. A significant concept was raised following an examination of the numerous publications. As a result, a conceptual design with estimated parameters was developed. A detailed study was conducted after the necessary software and electronics were selected, and accurate parameters were established. After that, the detailed design was modelled and used to create prototypes. Finally, the prototype was put to the test using hand gestures to produce the desired response in physical environments. Fig. 4 depicts the methodology that was developed.

IV. DETAILED DESIGN

In gesture-based robot arm control, computer vision is employed to control the hardware. As a result, the project focuses mostly on software design, with visual testing conducted using hardware via triggering motors with required motion. A single-shot detection model for mobile real-time use is built to recognize beginning postures of hands, comparable to the facial recognition model in MediaPipe Face Mesh. Hand identification is a difficult problem since the model must distinguish between occluded and self-occluded hands despite operating with a diverse size range of the hands and a wide scale time frame in relation to a captured image. Regression is utilized to accomplish exact localized key point of 21 3D hand-knuckle points inside the identified hand regions, i.e. direct point predictions, after palm identification across the whole picture. To get ground truth data, 30 thousand actual pictures were manually tagged with 21 3 dimensional coordinates, as shown in Fig. 6. A best quality artificial hand model was created across different backdrops and mapped to the appropriate 3-dimensional coordinates to better cover the possible hand postures and provide more oversight on the nature of hand geometry. The 21-point hand landmarks are shown in Fig.7. The media pipe hands algorithm analyzes real-time images and determines which palm belongs to which hand. 21-point coordinates are mapped after palm detection. The top three coordinate points are taken in all fingers from the tip to the bottom, a line is drawn connecting the three spots, and the angle between the three points is measured. The five-finger angle is recorded in the list values and communicated to the Arduino via serial communication. According to our gesture, the Arduino controls the servo motor in real time.

V. CONCEPTUAL DESIGN

The project is primarily concerned with software architecture, with the software being implemented through interfacing it with hardware for physical testing and analysis. The algorithm's creation and implementation may control any type of articulated robot for any industrial application. The programming languages utilized are Python and embedded C. The Arduino Uno is the microcontroller that operates and controls the actuators. The actuators used in the work are DC Servo motors. A web camera captures the image, which is then processed using a pre-trained machine learning pipeline. The capturing and processing program are written in Raspberry Pi and is used to acquire data from the image and send it to Arduino. The servo motor is commanded to make the desired gestures.

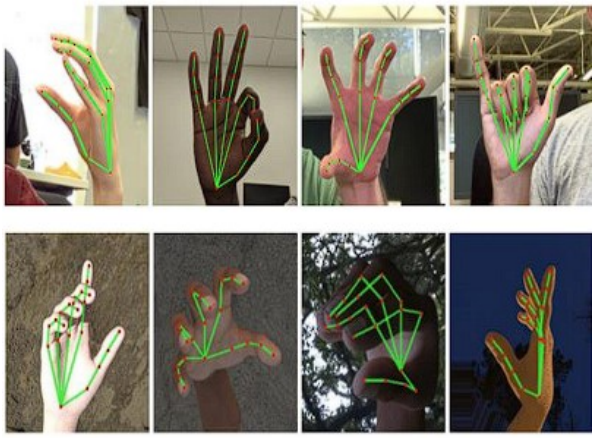

Fig. 4. Various Hand Tracking Coordinated

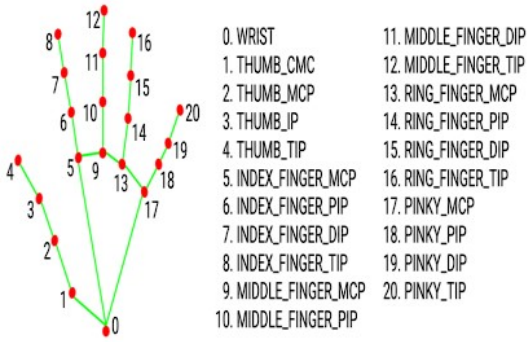

Fig. 7. Hand Landmarks

VI. CONCLUSION

Gesture Based Robot Arm Control using OpenCV has been implemented and developed in this project. The interfacing of software and hardware is done and the desired output is achieved according to the given input. This project shows the accurate and feasible approach to control the robot arm using gestures. More packages have been installed to increase the efficiency of the actuations performed.

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