IoT-Based Control Interface for a Robotic Arm for Object Organization

Survi Shireesha[1], Sheelam Jhansi[2], Erravelly Navya[3], Raj Kumar[4], Mr. P. Sathish[5]

[1,2,3,4]Students, Department of Computer Science and Engineering, Sree Dattha Group of Institutions, Sheriguda, Ibrahimpatnam, Telangana, India

[5]Assistant Professor, Department of Computer Science and Engineering, Sree Dattha Group of Institutions, Sheriguda, Ibrahimpatnam, Telangana, India

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Abstract: Automating industrial processes has greatly increased safety, accuracy, and productivity. This project shows off a robotic arm that can sort objects and has an IoT-based control interface. It can automatically find and sort items using smart control and remote surveillance. The system has a robotic arm that is powered by servo motors that are standard and operated by a computer's that can connect to the Internet of Things (IoT), like an ESP32 or NodeMCU. Sensors detect objects that have been placed in the sorting area, and the robotic arm sorts them into the correct places based on predetermined criteria like type or position. The IoT-based control user interface lets people check on and management the robotic arm from a web or mobile app. This system cuts down on the amount of work people have to do, makes sorting more accurate, and gives real-time operating information, making it perfect for smart manufacturing environments today.

I. INTRODUCTION

Robot are used in various environment ranging from homes to industries to provide assistant to human for a range of purpose such as operation in hazardous situations or operation in manufacturing sector [1]. The design of a robot can be varied depending on its function, application and the environment. Robotic arm is most commonly used in industry such as manufacturing and assembling. The use of robotic arm is to overcome human inefficiency in performing repetitive task such as pick and place operation. Robotic arm is a reprogrammable and multifunctional manipulator design to assist human in various surroundings. Robotic arm is able to overcome human inefficiency in performing repetitive task such as pick and place. Thus, industry such as assembly and manufacturing have widely integrated robotic arm into their assembling line to overcome the problem of human inefficiency [2-4]. Internet of things (IoT) allow data to be exchange between devices through the connection of many devices [5, 6]. Internet connection has fundamentally changed the arrangements for monitoring and control and the use of open or public standards and personal computer systems (PCs, tablets, smart phones) bring significant benefits to their users and producers [7]. This concept can be further extended to be integrated into various wearable energy harvesting devices [8] and implantable wireless biomedical applications, such as wireless micropumps, micromixers, and microvalves [9-11]. The capabilities and the functionality of a robot depends largely on the needs and its environment. Robot will then be varied accordingly to suit the needs. For example, robotic arm has been widely integrated into industry or factory to assist human in performing repetitive task. The used of robotic arm in industry promotes better product quality, productivity and increase efficiency [12, 13]. Most of the time, robotic arm is required to be train or teach before it can spring into action. The training or teaching process are normally carried out through teach pendant in a certain distance within the factory. The training or teaching process on the robotic arm will pose a great challenge in the absence of the relevant person in charge or engineer [14-17]. This is due to the fact that the training process on a robotic arm requires an in-depth knowledge not only on the robotic arm but also on the surrounding environment and material that the robotic arm will be handling. The integration of IOT with robotic arm allows smart industry to be realized. The purpose of this research is to design and build a three degree of freedom (DOF) robotic arm with a two-finger mechanical gripper. The robotic arm can be controlled remotely through android mobile device (AMD) to perform pick and place operation [18].

II. RELATED WORK

"Smart Robotic Assistant,"

A. Kumar, A. Mishra, P. Makula, K. Karan, and V. K. Mittal.

Smart robotic assistants help human beings in reducing the manual efforts in day-to-day tasks and the risk to precious human lives in hazardous situations. In this paper, we develop a smart robotic assistant that operates on human voice commands, given remotely by using an Android platform based smart IoT device. The real-time signal processing of the voice commands is carried out using a cloud server. The speech command signal converted to text form is then communicated to the robotic assistant over a Bluetooth network. The robotic assistant is developed on an Arduino micro-controller based platform. The robotic assistant is capable of performing different movements such as turns and start/stop operations, and picking up an object from one location and placing it at another location. The effectiveness of the voice commands given over the network is measured through several experiments. Performance evaluation results are encouraging. Potential applications of this smart robotic assistant in homes, hospitals and industries are discussed.

"Application of Robotics in Onshore Oil and Gas Industry - A Review Part I,"

A. Shukla and H. Karki.

With ever increasing global demand and depleting resources for fossil fuels, oil and gas industry is now positively looking for advanced robotic solutions to increase their productivity and safety. With time easy resources of the fossil fuels are shrinking and newly searched reservoirs, to feed supply demands of global consumption, are mostly located in extreme environmental conditions such as hot deserts, deep water and arctic zone etc. Production of the fossil fuels, in such inhospitable environmental conditions, poses difficult challenges to health, safety and environment (HSE). Tragic incidents like Exxon Valdez and Deepwater Horizon oil spills are examples of such challenges. Therefore, oil and gas industry has lot to learn from successful implementation of robotics and automation for dull, dirty and dangerous (3D) tasks of manufacturing industry. Most of the robotics technologies, currently used in the oil and gas industry, are mainly focused on inspection, maintenance and repair (IMR) of plant facilities with higher frequency and accuracy. Fundamental idea, involved in the automatization of these processes, is based on the principle of teleoperation with skilled operator. Automation of 3D tasks not only improves HSE standards but also lead to much needed economic efficiency by reducing production cycle, floor space and number of staff members required for continuous inspection and manipulation of plant facilities. Considering the risks involved in this industry usage of completely autonomous robots, first without achieving very high reliability, is still a far fetch choice. Therefore, semi-autonomous robots, where actions are performed by robots but cognitive decisions are still taken by skilled operator, is an excellent choice for this industry as a near future solution. In the onshore oil and gas industry robotic solutions are used both in upstream and downstream processes, such as site survey, drilling, production and transportation, mainly focused in the form of in-pipe inspection robots (IPIRs), tank inspection robots (TIRs), unmanned aerial vehicles (UAVs) and wireless sensor networks (WSNs) etc. This paper presents the state of art robotic solutions currently used in onshore oil and gas facilities.

"Design and Control of Robot Manipulator with a Distributed Actuation Mechanism,"

S.-H. Kim, Y. J. Shin, K.-S. Kim, and S. Kim.

This paper presents a design methodology based on the distributed actuation principle to achieve a high-performance robot manipulator. Spatial movement of the actuation points provides several advantages such as high payload capacity, high efficiency and a light weight structure for the proposed robot manipulator. Based on the analysis, the distributed actuation mechanism using a single slider is adopted for the proposed manipulator. A prototype of the manipulator with two degrees of freedom is developed and controlled as an example. The efficacy of the proposed approach is verified experimentally.

"IoT Based Robotic Arm for Industrial Automation"

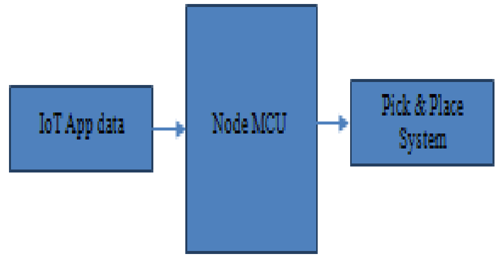
Sharma, R.

This paper discusses the integration of IoT with robotic arms for industrial automation. The authors propose a system using servo motors and microcontrollers to perform object sorting tasks. IoT connectivity enables remote monitoring and control, improving efficiency and scalability. The study concludes that IoT-based robotic arms are cost-effective and suitable for modern manufacturing environments.

III. IMPLEMENTATION

The proposed Robotic Arm for Object Sorting integrates servo-controlled robotic mechanisms with an IoT-enabled microcontroller. The system detects objects using sensors and processes the data to determine the appropriate sorting category. The robotic arm then picks the object and places it in the corresponding bin. Through the IoT-based control interface, users can monitor system status, control operations, and view sorting data in real time from a remote location. This intelligent system enables efficient object handling, improves sorting accuracy, and allows centralized supervision, making it ideal for automated and smart industrial applications.

Block Diagram



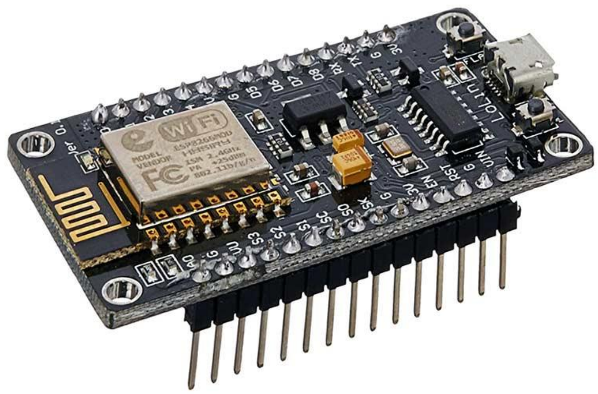
Working

The Robotic Arm for Object Sorting system works by combining IoT connectivity with automated pick-and-place operations to improve industrial efficiency. A microcontroller such as ESP32 or NodeMCU controls servo motors that drive the robotic arm, while sensors detect objects placed in the sorting area. Based on predefined criteria like position or type, the arm intelligently performs sorting by moving items into designated locations. Through an IoT-based control interface, users can monitor and operate the robotic arm remotely via a web or mobile application. This integration reduces human effort, enhances sorting accuracy, and provides real-time operational data, making it a practical solution for modern smart manufacturing environments.

HARDWARE REQUIREMENTS

Node MCU

Technically speaking NodeMCU is a firmware for ESP8266 developed using C Programming Language, Espressif NON-OS SDK and Lua scripting language. Traditionally, we write code for our Microcontrollers like Arduino, STM32, 8051 etc., either in C or C++ and compile it with a set of tools and generate a binary file. This binary file is then uploaded into the flash memory of the microcontroller and it gets executed. Things are quite different with NodeMCU. You can consider the NodeMCU firmware as an interpreter for Lua Scripts. So, if your ESP8266 is loaded with NodeMCU Firmware, you can simply write your application in Lua and send it to the ESP8266.NodeMCU Firmware will interpret the byte code and executes the commands. There is no compilation, no binary file etc. Just write a script and run it the team which developed NodeMCU Firmware also developed a breakout board for ESP-12E module called the NodeMCU Devkit. So, many of us are actually using the board called NodeMCU and programming it with Arduino IDE and not the Lua Scripts.



IMPORTANT NOTE: Only one firmware can exist on the ESP8266. It can be either AT Commands Firmware, NodeMCU Firmware or Arduino based code. Once you upload an Arduino sketch, the NodeMCU firmware gets erased. If you want to work with Lua Scripts and NodeMCU, then you have to flash the NodeMCU Firmware.

ESP-01 vs. NodeMCU (ESP-12E)

As mentioned earlier, the NodeMCU Devkit is actually a Breakout Board for the ESP-12E Module. The ESP-01 is the vanilla version of the ESP8266 Wi-Fi SoC made by Ai–Thinker, a third part module manufacturer for ESP8266.

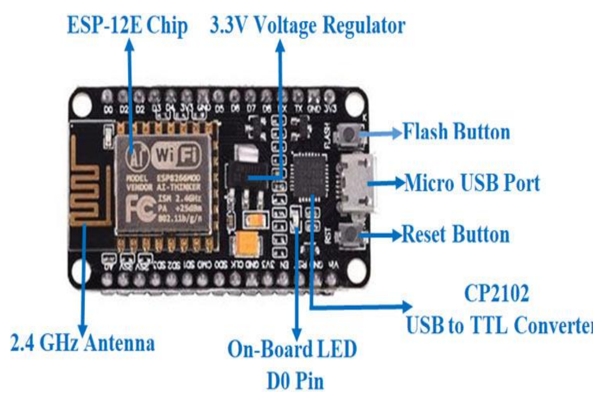
Brief about NodeMCU ESP8266

The NodeMCU ESP8266 development board comes with the ESP-12E module containing the ESP8266 chip having Tensilica Xtensa 32-bit LX106 RISC microprocessor. This microprocessor supports RTOS and operates at 80MHz to 160 MHz adjustable clock frequency. NodeMCU has 128 KB RAM and 4MB of Flash memory to store data and programs. Its high processing power with in-built Wi-Fi / Bluetooth and Deep Sleep Operating features make it ideal for IoT projects.

NodeMCU can be powered using a Micro USB jack and VIN pin (External Supply Pin). It supports UART, SPI, and I2C interface.

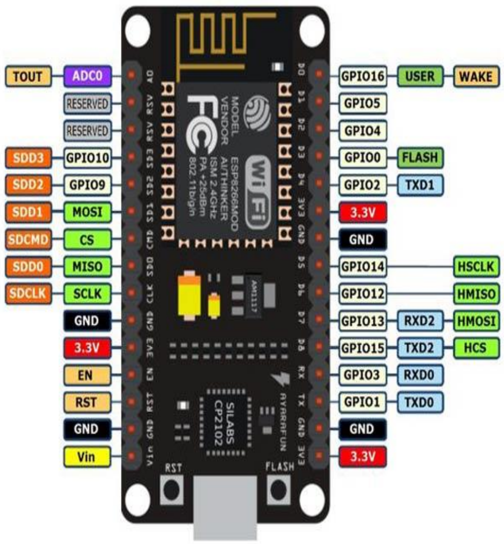
- **ESP8266 Chip**: The core of the NodeMCU module is the ESP8266 chip, which provides Wi-Fi connectivity and microcontroller functionality.
- **GPIO Pins**: The NodeMCU board includes multiple digital and analog pins that can be used to connect various peripherals such as sensors, LEDs, and motors.
- **Serial Communication Protocols**: It supports UART, SPI, and I2C protocols, enabling communication with other devices and modules.
- **Open-Source Firmware**: The NodeMCU firmware is open-source and based on the Lua scripting language, making it easy to program and customize.

Compact Design: The NodeMCU module is small and lightweight, making it suitable for various applications, from hobby projects to professional IoT solutions



ESP8266 Wi-Fi module

ESP8266 comes up with powerful processing speed on board. Storage space of this module is also high allowing it to integrate with other devices like sensors. To make this module compatible with other development boards, we have to do level shifting of voltages externally because this board doesn't come up with on-board voltage regulator. This module is cost effective and thus used widely in many applications like the Internet of things and much more. So in this article, we are going to discuss key features of ESP8266, pins specifications, how to use this board for programming purposes and a sample program.



NodeMCU ESP8266 Specifications & Features

The Node MCU module is built around the powerful ESP8266 microcontroller, which is well-suited for IoT applications due to its integrated Wi-Fi capabilities and robust processing power. Here's a detailed look at its specifications:

Microcontroller: Tensilica 32-bit RISC CPU Xtensa LX106

The core of the NodeMCU is the Tensilica Xtensa LX106, a 32-bit RISC CPU known for its efficiency and performance in handling complex tasks with low power consumption.

Operating Voltage: 3.3V

The module operates at a standard 3.3V, making it compatible with a wide range of sensors and peripherals that also use 3.3V logic levels.

Input Voltage: 7-12V

It accepts an input voltage range of 7-12V, which is regulated down to 3.3V by the onboard regulator, ensuring stable operation and protecting the microcontroller from voltage fluctuations.

Digital I/O Pins (DIO): 16

The NodeMCU provides 16 digital input/output pins that can be used to interface with various sensors, actuators, and other digital devices. These pins can be programmed for general purpose use, such as reading sensor data or controlling LEDs.

Analog Input Pin (ADC): 1

There is one analog input pin available, allowing for the connection of analog sensors. This pin can read voltage levels and convert them into digital values for processing.

UARTs: 1

The module includes one UART (Universal Asynchronous Receiver/Transmitter) for serial communication, which is essential for debugging and connecting to other serial devices.

SPIs: 1

One SPI (Serial Peripheral Interface) is available, providing high-speed communication with devices like SD cards, displays, and other SPI peripherals.

I2Cs: 1

The I2C (Inter-Integrated Circuit) bus allows for communication with multiple I2C devices using only two wires, making it ideal for connecting sensors and modules that support I2C communication.

Flash Memory: 4 MB

The NodeMCU is equipped with 4 MB of flash memory for storing the firmware and user programs. This ample storage space allows for the development of complex applications and features.

SRAM: 64 KB

It includes 64 KB of SRAM (Static Random Access Memory) for data storage and processing during runtime. This memory is used for variables, data buffers, and program execution.

Clock Speed: 80 MHz

The microcontroller operates at a clock speed of 80 MHz, providing sufficient processing power for handling various tasks efficiently and in real-time.

USB-TTL based on CP2102:

The onboard CP2102 USB-to-TTL converter allows for easy programming and serial communication over USB. It enables plug-and-play functionality, simplifying the setup and development process.

PCB Antenna:

The NodeMCU features an integrated PCB antenna, which provides reliable Wi-Fi connectivity without the need for an external antenna. This design keeps the module compact and easy to use.

Compact Size:

The small form factor of the NodeMCU module makes it ideal for integration into IoT projects, where space is often limited. Its compact size allows it to fit seamlessly into a wide range of applications, from home automation to wearable devices.

PICK AND PLACE ROBOT

Simply put, pick and place robots are a category of industrial robots designed to efficiently lift objects from one location and place them in another. They have been around since the 1960s, and today, pick-and-place robots are a staple in modern warehouses, automating tasks that range from complex operations to simple, repetitive ones.

Renowned for their speed, accuracy, and efficiency, pick and place robots have become indispensable in industries such as manufacturing, packaging, and logistics. They have also significantly reduced workplace injuries by taking on hazardous tasks traditionally performed by humans, such as stacking heavy parcels and packages.

In this article, we'll dive deep into what is a pick and place robot, how they work, and why they could be the ideal solution for your business.

Key components of a pick and place robot

While software provides a strong foundation for pick-and-place robots, it is meaningless without the hardware's capabilities and flawless integration between the two.

Here is how the hardware and software components come together to form efficient pick and place robots:

1. Robotic arm

Depending on the type of robot, the arm is typically designed to minimize cycle duration—a critical metric that measures the time it takes for the robot to start, complete a task, and return to its starting position.

The robotic arm, though a system in itself, is just one part of the overall pick-and-place solution. Factors such as the warehouse's space, required capabilities, item volume, and reachability determine the selection of a robotic arm to efficiently move items from point A to point B.

Once the hardware design is finalized, the robot is programmed and integrated with sensors, controllers, end-effectors, and other essential components, enabling it to perform tasks with speed and precision.

2. End effectors

End effectors function as the "hands" of robotic arms, serving as the point of contact between the robot and the object it interacts with. The design of the end effector varies depending on the types of objects needed to be handled. Common types include:

Vacuum grippers: Uses suction to pick up sealed items or boxes. However, this type of gripper is not suitable for open or porous boxes.

Mechanical grippers: Finger-like clasps designed to handle objects of various shapes and sizes. Keep in mind, these grippers require open space around them to function effectively.

Magnetic and Adhesive grippers: Ideal for handling heavy iron or metal objects, often used in production lines.

3. Sensors

Sensors are critical for guiding and ensuring the pick-and-place robot's precision. Different types of sensors serve unique purposes:

Vision sensors: These are sensors equipped with 2D or 3D cameras, allowing the robot to "see" and identify objects, guiding it on what to pick and how to grasp it. Our custom-engineered vision software identifies items without SKU teaching and uses artificial intelligence to learn from each pick, improving accuracy and ensuring collision avoidance.

Force sensors: Found in the end effector (the "hand" of the robot), these control how hard the robot grips an item, preventing damage to delicate objects. Force sensors also measure an item's weight to ensure the robot handles the correct quantity based on the predetermined number of items specified in the system.

Proximity sensors: These sensors detect obstacles or objects in the robot's workspace, ensuring it avoids collisions with items or human operators.

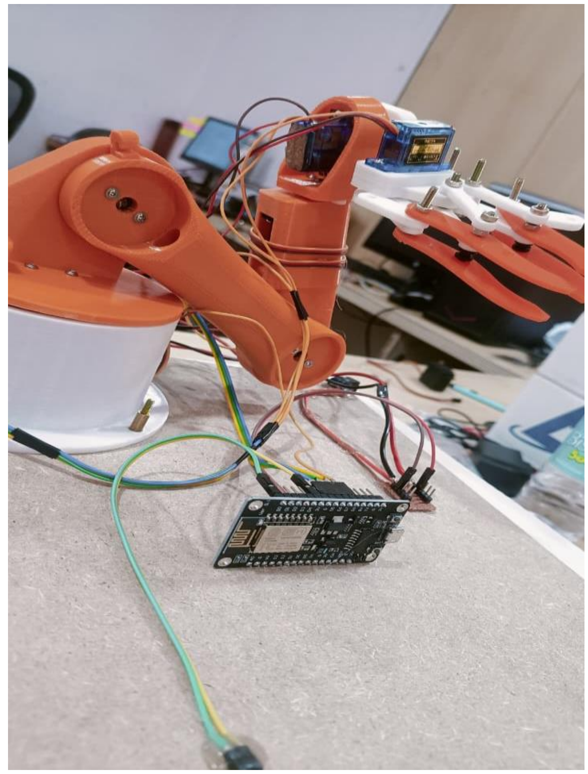
4. Controllers & movement control

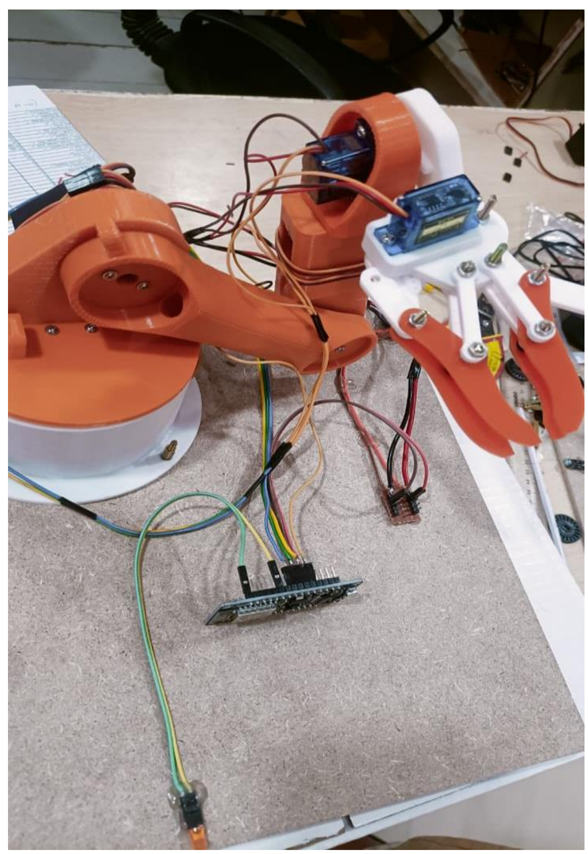
Controllers act as the CPU or brain of the pick-and-place robot, flawlessly combining hardware and software to execute actions. They process input from sensors to determine the robot's next moves.

At Smart Robotics, we've developed our own motion and task planning technology, much like our vision software, to work in harmony with sensors. This integration allows the robot's intelligence to choose the fastest path and handle tasks like vision processing while on the move. This not only accelerates cycle times and boosts throughput but also ensures gentle product handling.

Additionally, our task planning software adjusts the robot's speed based on its surroundings—increasing speed when no human operators are nearby and slowing down when human operators are detected in the vicinity, ensuring safe and controlled operation.

IV. RESULT ANALYSIS





V. CONCLUSION

The Robotic Arm for Object Sorting with IoT Based Control Interface demonstrates how robotics and IoT can be combined to create intelligent, efficient, and scalable solutions for industrial automation. By integrating sensors, servo motors, and IoT platforms, the system ensures accurate sorting, reduced human effort, and real-time monitoring. Its adaptability and cost-effectiveness make it a valuable tool for smart manufacturing environments, contributing to productivity and sustainability.

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