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IoT-Based Centralized Governing System for Industrial Automation Using Raspberry Pi

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A B S T R A C T

This system aims to design and implement a centralized governing system for industrial automation using Raspberry Pi, which can monitor various parameters such as door access, HVAC, lighting, camera surveillance, and power consumption through a GUI and Web UI. Being in one place users will get access to all the machinery in the industry. The Raspberry Pi, being a low-cost microcontroller, is used as the main processing unit, along with sensors and actuators to monitor and control the various parameters. The proposed system offers several benefits such as improved efficiency, reduced energy consumption, enhanced security, and increased convenient. The main objective of this system is develop a control system using Raspberry pi and IoT to control and monitor various industrial automation system including doors, lights, HVAC, power, and cameras and also to design and implement a user-friendly interface to control and monitor the different systems remotely using smartphone, or computer. This system collects data to optimize the system's operation and improve its efficiency over time.

Keywords: HVAC, GUI, Web-UI, Raspberry Pi.

1. Introduction:

The Raspberry Pi serves as the main control unit, while the CODESYS software provides the programming interface and logic control capabilities. We demonstrate the ability to control the Raspberry Pi using CODESYS to monitor and control various processes in real time. For controlling the devices, we can use Bluetooth, RF, and GSM systems but all the systems are limited in their range and controlling features. But in the case of our system, we are not limited to range and features. We can control devices from anywhere in this world through TCP/IP protocol. The system will use IoT technology to connect and control various industrial processes and equipment from a single location, and will also include the capability to monitor the facility using cameras , door close sensors and other safety measures. Raspberry pi serves as a server to communicate with Web-UI and HMI of the factory through TCP/IP protocol.

In the previous work the factory machinaries are monitored and controlled using, Bluetooth, GSM system etc,. through this system all the machinaries and parameters like sensors and actuators, cameras, doors and power usage of the machinaries are observed through Web-UI, also the data reports are stored in the system for further processing. A user-friendly interface has also been designed to remotely control and monitor the different systems using a smartphone or computer. With the ability to collect data and optimize the system's operation, the proposed system aims to improve the efficiency of industrial automation over time. This paper presents an overview of the proposed system and its potential benefits for industries.

2. System Content:

Raspberry Pi:

The Raspberry Pi is a tiny single-board computer that is about the same size as a credit card, and it is inexpensive. This computer was created by the Raspberry Pi foundation in the United Kingdom, and it is considered an innovative part of computer technology (What is a Raspberry Pi? n.d.). People from various backgrounds and skill levels can use it to learn about computing. Additionally, this minicomputer can be linked to other peripheral hardware such as a monitor, keyboard, and mouse (Raspberry Pi, 2019). It features a 64-bit quad-core processor running at 1.4GHz, dual-band 2.4GHz and 5GHz wireless LAN, Bluetooth 4.2/BLE, faster Ethernet, and PoE capability via a separate PoE HAT. The board is designed for modular compliance certification, allowing for easy integration into end products with reduced wireless LAN compliance testing, resulting in cost and time savings. Its mechanical footprint is the same as both the Raspberry Pi 2 Model B and the Raspberry Pi 3 Model B, making it a seamless upgrade for those familiar with these models. The Raspberry Pi 3 Model B+ is a reliable and cost-effective choice for industrial automation projects that require high processing power and wireless connectivity.

Table 1 - Specification. [Raspberry Pi 3B+]

Processor	Broadcom BCM2837B0, Cortex-A53 64-bit SoC @1.4GHz
Memory	1GB LPDDR2 SDRAM
Connectivity	• 2.4GHz and 5GHz IEEE 802.11.b/g/n/ac wirelessLAN • Bluetooth 4.2, BLE Gigabit • Ethernet over USB 2.0 (maximum throughput300Mpbs) 4 x USB 2.0 ports
Environment	Operating temperature, 0–50°C

Codesys:

Raspberry Pi was programmed using the CODESYS 3.5 programming tool,developed by Smart Software Solutions GmbH. Codesys stands for Controller Development System, (Why CODESYS?.2019). it is a hardware- independent programming system for industrial automation technology that complies with IEC 61131-3 standard. It supports all five languages described by the standard, as well as other basic PLC programming attributes and features. (Hanssen, 2015, p. 486).

2.2.1. Ladder Diagram

Ladder Diagram is a graphical programming language that you use to develop software for programmable logic controllers (PLCs). It is one of the languages that the IEC 61131 standard specifies for use with PLCs. A program in ladder diagram notation is a circuit diagram that emulates circuits of relay logic hardware.

Fig. 1 Ladder Diagram Programming in Codesys

Communication Protocols

Communication protocols are formal descriptions of digital message formats and rules, required to exchange messages in or between computing systems. The protocols describe communication by defining the rules of authentication, error handling, signaling, syntax, semantics, and synchronization (Communication Protocol, 2019). The section below provides descriptions of the communication protocols used in this project.

TCP/IP:

TCP/IP, or the Transmission Control Protocol/Internet Protocol, is a family of network protocols that are used for the connection and communication of devices on the internet or private networks. TCP/IP regulates data exchange by specifying how it can be divided into packets, addressed, transmitted, routed, and received at the destination. TCP/IP protocols were developed to provide network reliability and sustainability (Rouse, 2019). TCP/IP protocol uses the client/server model, in which the server computer provides service to another machine or user. TCP/IP communication happens at several different levels, and it can be divided into four layers. The physical layer contains protocols that operated on a link and are responsible for physical connections inside the network, such as Ethernet or Address Resolution Protocol. The network layer sometimes referred to as the internet level, is related to the interconnection of independent network, data packets, and their transmission across the networks. The network layer includes IP and Control Message Protocol, the protocol for reporting errors. The transport layer maintains end-to-end communication between hosts and provides flow control, multiplexing, and reliability. The application layer is needed for standardized data exchange between applications. It consists of such protocols as

Hypertext Transfer Protocol, File Transfer Protocol, Post Office Protocol 3, Simple Mail Transfer Protocol, and Simple Network Management Protocol (Rouse, 2019).

SSH:

Secure Shell is a communication protocol that provides a secure login to a remote computer. SSH uses the client/server model, where connection 16 to the server computer is initiated by the client. The SSH client operates the setup of the connection and uses public-key cryptography to verify the identity of the SSH server. The simplified model of an SSH connection is illustrated in Fig 2. (Ylonen, 1996). The most common uses of SSH include providing secure access for user and automated processes, interactive and automated file transfers, issuing remote commands, and managing a network infrastructure and other mission-critical system components (Ylonen, 1996,)

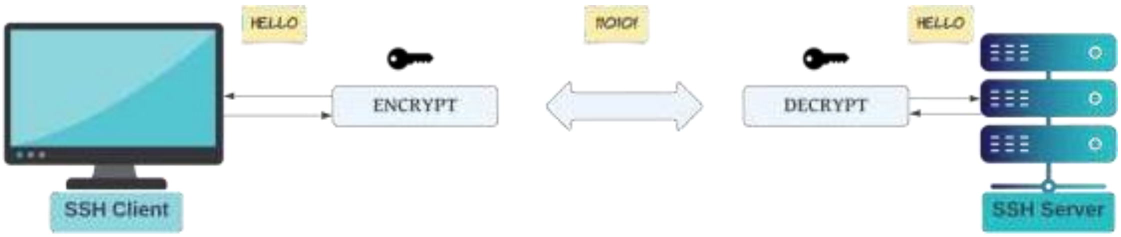

Fig. 2 SSH Connection

The most common uses of SSH includes providing secure access for users and auromated processes, interactive and automated file transfer. Issuing remote commands, and managing a network infrastructure and other mission-critical system components (Ylonen, 1996, pp. 37-42).

I2C:

Inter-Integrated Circuit (I2C), sometimes also referred to as Inter-IC, IIC, or I²C, is a widely used serial bus protocol designed by Philips in the early1980s.The protocol is used for communicaton between electrical components on the same board, low-speed devices, such as microcontrollers, IO modules, or other peripherals in the embedded systems. (I2C Info – I2C Bus, Interface, and Protocol, 2019). The protocol is flexible and easy to use, as it is based on simple master-slave relationships between the components and requires only two wires to connect an almost unlimited number of controllers. The bus lines are SDA (serial data) and SCL (serial clock). Both of them require pull-up resistors to the positive supply voltage. Since the bus clock is generated by the master device, I2C bus communication does not have strict 17 specifications for baud rate as, for instance, RS232 protocol. What is more, the I2C bus is a true multi-master that provides collision detection and

arbitration. (I2C Info – I2C Bus, Interface, and Protocol, 2019).

3. Methodology:

Raspberry Pi was programmed using the CODESYS 3.5 programming tool, developed by Smart Software Solutions GmbH. Codesys stands for Controller Development System, it is a hardware-independent programming system for industrial automation technology that complies with IEC 61131-3 standard. It supports all five languages described by the standard, as well as other basic PLC programming attributes and features.

Preparation of Raspberry pi:

First of all, an operating system (OS) had to be installed on the Raspberry Pi. BUSTER is a simple OS installer, provided by Raspberry Pi Foundation. It can be downloaded from the official Raspberry Pi website and extracted to an empty SD card. Once the card with Buster is inserted into a Raspberry Pi, it prompts a selection of operating systems that can be installed on the Raspberry Pi. When the Raspberry Pi was turned on, the OS selection was made in BUSTER – Raspbian, the desktop version without additional software. Raspbian is the officially supported Linux-based OS for Raspberry Pi. More information about the OS version can be found in the screenshot in Fig 3.

Fig. 3 Raspberry Pi OS version

Once the OS installation was completed, some of the basic settings needed to be checked. Firstly, the localization of the Raspberry Pi was set to Asia. Since Raspberry Pi does not have a real-time clock, it synchronizes its time settings with the Internet. Localization settings config it to use the right time zone. Secondly, the interfacing values were checked and SSH and I2C communication interfaces were enabled, as shown in Fig 4.

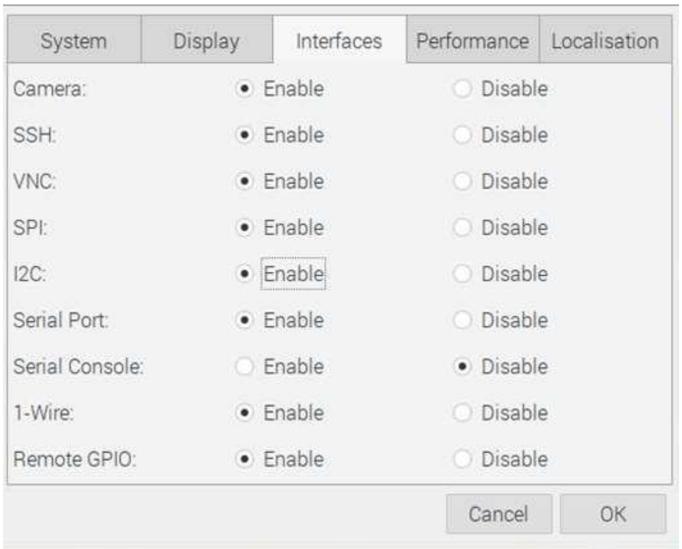

Fig. 4 Configuration of the communication interfaces of Raspberry Pi

Installing Codesys Application:

To allow CODESYS software to execute commands and download data to the Raspberry Pi, an SSH connection needed to be established between the computer and the microcontroller Hardware. After the SSH connection was established, the Raspberry Pi could be accessed and controlled by the CODESYS computer software. CODESYS runtime was installed on the Raspberry Pi directly from the computer application. Fig 5 shows the interface for installation and control of CODESYS runtime on Raspberry Pi. When the Codesys Control runtime system had been installed on the Raspberry Pi, it was possible to log in to the runtime, download a program and execute it. Fig 6 shows the connection to the Raspberry Pi as a target device.

Fig. 5 Control of Raspberry Pi runtime in CODESYS

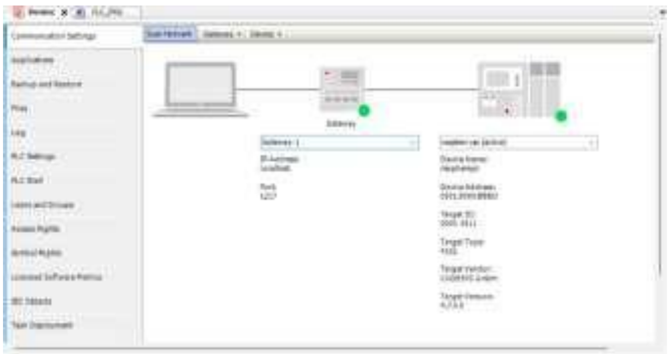

Fig. 6 Connection to Raspberry Pi in CODESYS

HMI Interfacing:

We control and monitor a CNC machine. Here we have a Raspberry pi GPIO pin connected to the HMI of the CNC machine as shown in Fig 7. The selected hardware components such as sensors and actuators will be procured, and the system's physical components will be assembled based on the system design. The Raspberry Pi will be programmed as a PLC, and the sensors and actuators will be interfaced with the Raspberry Pi using appropriate hardware interfaces.

Fig. 7 Connection to Raspberry Pi in CODESYS

Software Development:

The software for the system will be developed using CODESYS, a popular PLC programming software that supports a wide range of industrial controllers. The CODESYS environment will be used to create the control algorithm and the communication protocols for the sensors and actuators. The software will be tested for reliability and efficiency using simulation tools available in the CODESYS environment. The programming language used in CODESYS is based on IEC 61131-3 standard, which is widely used in industrial automation.

Raspberry pi camera module:

The Raspberry Pi has a built-in camera module, we can access the module by connecting the host pc with the same connection. We used a raspberry pi version 2 camera. Camera modules are used to monitor the view of overall conditions in the industry. The process is to connect the Raspberry pi with a Wi-Fi connection, after that, we need to connect the host pc with the same Wi-Fi connection as we are controlling the pi through SSH. Then from the host pc connection on the network tab, we need to connect pi's local IP address. After that, we can view the video locally. But for viewing it from a global endpoint we have to follow several steps. Firstly, we need to connect it to YouTube API. From there we can go live from the API on YouTube. After that, we can embed the iFrame into our host website. By this, we can view it globally.

Raspberry Pi power detection module

We used the INA219 power module to get the power unit measurement. INA219 module is used to detect shunt voltage and shunt current across the machine. So, we connect it to the motor driver module so that we can measure machine load power and low voltage current. And using i2c communication Raspberry pi can read the power usage of the machine and record the data on the server and also monitor through Web-UI.

Codesys Web Visualization

The Codesys visualization is a graphical representation of the project variables which allows inputs to the PLC program in online mode via mouse and keypad. The Codesys visualization editor, which is part of the programming system provides graphic elements which can be arranged as desired and can be connected with project variables and can create XML descriptions of the visualization objects and download them to the PLC. There a Web-Server will provide the PLC data in XML format too and thus can create continuously updated visualization that can be opened in the Web Browser of any computer which is connected via the Internet, independently from the target platform. The Web-Server can connect dynamically to several controllers if confided appropriately. In this case, the HMI (Fig. 7) is completely connected to Web-UI as shown in Fig. 8.

Fig. 8 Web Visualization

Simulation

Factory simulation is done using Factory I/O software. Factory I/O is a 3D factory simulation for learning automation technologiesFactory I/O enables the fast construction of virtual 3D factories by selecting among more than eighty configurable parts. Also, Factory I/O comes with over twenty ready-to-use typical industrial applications (also called scenes) to practice real-world control tasks. Furthermore, Factory I/O supports blending virtual and real information by replacing data/control signals simulated by software with information coming from real devices; that is Factory I/O provides many I/O points to plug actual PLCs, microcontrollers, data acquisition cards, FPGAs, etc.

Fig. 9 Factory IO

4. Block Diagram:

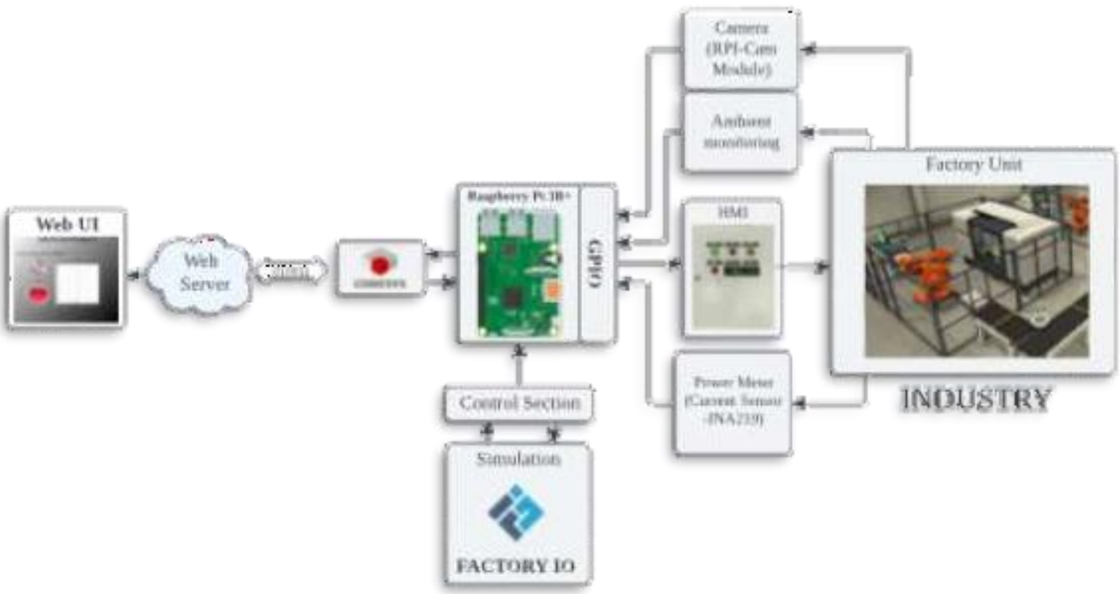

Fig. 10 Block Diagram of Proposed Project

The block diagram for the IoT-based centralized governing system for industrial automation using Raspberry Pi consists of four main components: the sensors, Raspberry Pi, web server, and web UI. The first component: the sensors, include cameras, power sensors, and ambient monitoring parameters, which are connected to the Raspberry Pi through GPIO pins. These sensors monitor various parameters such as door access, HVAC, lighting, camera surveillance, and power consumption in industrial automation. The second component is the Raspberry Pi, which serves as the main processing unit, receiving input data from the sensors and sending commands to the actuators. The Raspberry Pi also runs the web server software that allows the system to connect to the web UI. The third component is the web server, which communicates with the Raspberry Pi through a network connection. The web server receives and sends data from the Raspberry Pi to the web UI. The fourth component is the web UI, which provides a user-friendly interface to remotely monitor and control the industrial automation system. The web UI receives data from the web server and presents it to the user in a graphical format. The user can then control the system by sending commands to the Raspberry Pi through the web UI. Overall, the block diagram of the proposed system shows how the sensors, Raspberry Pi, web server, and web UI work together to create an efficient and cost-effective solution for centralized governing of industrial automation using Raspberry Pi and IoT.

5. Result and Discussion

A smart governing system is built with Raspberry Pi 3 model b+. This system helps to monitor our industries through web servers. We implement a very advanced system that contains camera monitoring, power measurement, temperature measurement, and door access through this system. Normally we used to check our sensor data instantly. But in this system, we can observe all data from the starting date to the ending date. And that’s how we can get monthly data reports. For controlling the devices, we can use Bluetooth, RF, and GSM systems but all the systems are limited in their range and controlling features. But in the case of our system, we are not limited to range and features. We can control devices from anywhere in this world through TCP/IP protocol. We connected raspberry pi with the Wi-Fi module and so, get connected to the internet. We take data from various parameters as included for factory automation and updated it on the web server. The data report can be viewed through the web server.

6. Conclusion

The centralized governing system for industrial automation using Raspberry Pi has developed to effectively monitor and control multiple industrial automation systems, including Doors, Lights, various industrial automation systems and also able to monitor and optimize energy usage in real-time. The system provides a low-cost, versatile and efficient solution for controlling and monitoring various industrial automation systems. The system can be further improved and scaled up to meet the specific requirements of larger industrial facilities.

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