Design and Implementation of Portable and Prospective Embedded System and IoT Laboratory Kit Modules

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Abstract: The purpose of this research is design and implementation a new design of a low-cost, portable and prospective laboratory kit module. Laboratory kits are made easy to assemble, with relatively small dimensions and suitable for laboratories with limited experimental space and funds. The research stages are carried out starting with needs analysis, hardware design, software design and overall testing. The test results of the DHT 11 temperature sensor shows it can read the temperature and humidity index while data in digital and displayed on the LCD. The PWM of DC motor and the direction of the motor rotation can be controlled using a push button. The keypad can control the direction of rotation of the servo motor and students are expected able to provide authentication through a password with a keypad. Testing result of the kit module for data communication using a local network to get Quality of Service (QOS) with throughput parameters on the Hypertext Transfer Protocol (HTTP) protocol close to 99.71%. This result include to the category of good quality network and overall test results of whole system is well. Perhaps this module will encourage students able to make technological innovation applications based on embedded systems and IoT and lead the creation of technology among students.

1 INTRODUCTION

Embedded system is a computer system specifically designed for a specific purpose in order to improve the function of a machine. The development of information technology today is marked by the presence of the Internet of Things (IoT). IoT is an internet service that is integrated with the use of certain types of sensors (Ghosh et al., 2016), (Khan, 2017) Currently, IoT-based embedded systems have been widely applied such as for health monitoring (E. Madona et al., 2018), (Yulastri et al., 2018), natural disasters (E. Madona et al., 2019), agriculture (Jan Bauer et al., 2018) and the industrial world (Breivold & Sandstrom, 2015). The ability of students to apply embedded systems is needed, especially in the world of working and other things. It was successfully applied to the Undergraduate Embedded System Education at Carnegie Mellon (Koopman et al., 2005). In the academic activity, many studies have been carried out on the Embedded system for its development (Mendoza et al., 2016), implementation of servo motor control (Bual et al., 2019), use of sensors (Bhadani & Vashisht, 2019) and DC motors (Sutyasadi & Wicaksono, 2020).

Laboratory practice activities are important activities for vocational education related to their experience in learning, thinking and solving problems (Indrianto et al., 2018). Limited equipment is a major problem for students causing students to not be able to experience learning.

The learning process is not optimal because of inadequate laboratory equipment. Computer simulation is an alternative for these problems (Anggara et al, 2019) such as LabView (Deaky et al., 2011), Matlab (Espinosa & Thiel, 2017) and others. This software uses a license whose budget is not affordable by the laboratory. The use of plants for IoT-based industries for learning is impossible because it is very expensive. In this study, a new design for a low-cost, portable laboratory kit module was created for use in embedded systems and data communication practicum in the Electronic Engineering Study Program, Electrical Engineering Department.

Some related researches are study conducted by (Indrianto et al., 2018) showed an increase in student learning scores of 7.8% by using the module for embedded systems practicum activities. Making a cargo transporting robot (Buditjahjanto et al., 2020)

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applied it method as a learning medium for microcontrollers, the results of the study show that the prototype made can be used in the teaching and learning process. A similar study was also conducted by (Ali et al., 2018) making the MCS51 microcontroller practical module which is portable and lower power consumption. Developments of previous studies are (1). Practical modules are integrated in one PCB board with low power consumption and portable. (2). Integrated with LAN Modules, Wireless and sensors for Internet of Thing (IoT) applications. Miniaturization is the contribution of this research.

The purpose of this research to design and implementation a new design of a low-cost, portable and prospective laboratory kit module. Laboratory kits are made easy to assemble, with relatively small dimensions and suitable for laboratories with limited experimental space and funds. This module kit consists of arduino embedded system modules, mcu nodes, LAN modules for data communication and sensors with various features. It is hoped that this module will encourage students to be able to create technological innovation applications based on embedded systems and IoT which will lead to the creation of technology in between students.

2 METHOD

The learning of Embedded Systems and data communication (IoT) are needed practical activities, so students become more understand and have skills while they graduate. Based on the results of the analysis, we propose this practicum module to overcome the previously identified problem, namely the absence of an Embedded System and data communication (IoT) practicum module. This module consists of input block, process block and output block as shown in Figure 1.

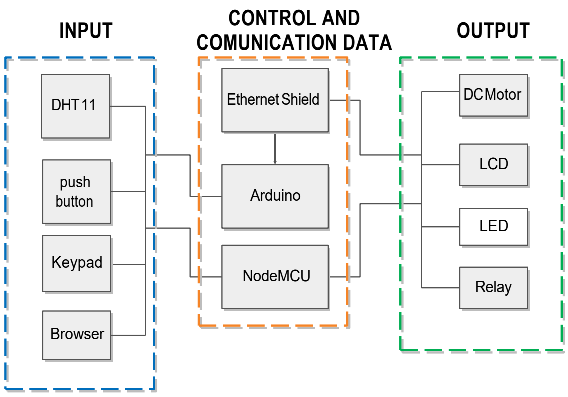

Figure 1: Block Diagram of the practicum module.

Based on Figure 1, the operation of this practicum module is divided into three parts, namely input, process and output. Input consists of DHT, push button, keypad and browser. DHT11 reads the temperature and sent the data to the Arduino digital pin. Browser provides input to Arduino via Ethernet network and Browser provides input to NodeMCU via wireless network. Once data receive, it will processed on the Arduino uno or NodeMCU according to its use. The using of Arduino is required if the input only wants to be processed directly to the output and using Ethernet communication. But if the system use the wireless feature as an output, it can use NodeMCU. Furthermore, the data has been processed by the microcontroller is issued to several available outputs including LCD, DC Motor, LED and Relay. The LCD will display characters in the form of text or numbers. The DC motor works to issue a movement that can be adjusted via PWM. LED to display an indicator in the form of light. The relay works as an automatic switch.

2.1 Design of Embedded System Kit Module and Data Communication

The design process starts with the creation of the circuit. This circuit consists of a temperature and humidity detector using a DHT11 sensor, push button, LCD, Led, relay and dc motor. DHT11 is connected to the VCC Pin on the Arduino Uno to provide an input voltage of 5V, then the DHT 11 GND Pin is connected to the Arduino GND Pin, the DHT 11 Data Pin is connected to Arduino Pin 2. Then on the LCD, 4 PINs are used, namely VCC, GND, SDA and SCL. The VCC and GND pins are connected to the customized pins on the Arduino, the SDA Pins are connected to the Analog A4 Pins and the SCL Pins are connected to the Analog A5 Pins. Then on the Motor pins that are used only the Positive Motor and Negative Motors are connected to the adjusted Pins on the Arduino Pins as shown in figure 2.

In the LED circuit, the LED Pin 1 is connected to the digital pin 10 on the Arduino Uno and the GND Pin is connected to the Arduino GND Pin. LED 2 is connected to digital pin 11 on Arduino Uno and GND Pin is connected to Arduino GND Pin, LED 3 is connected to digital pin 12 on Arduino Uno and GND Pin is connected to Arduino GND Pin, Data Relay pin is connected to digital pin 3.

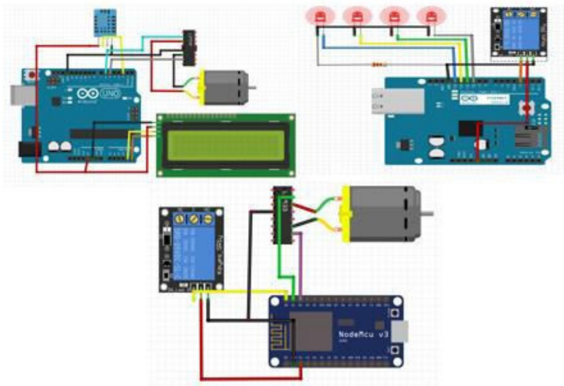

Figure 2: The practical module electronics circuit.

As for DC motor circuit, Data Pin 1 on the DC Motor is connected to Pin D1 NODEMCU and Data Pin 2 is connected to pin D2 NODEMCU. The Data Relay pin is connected to the D0 pin of the NODEMCU and the VCC and GND pins correspond to the VCC and GND pins of the NODEMCU. The practical module design can be seen in Figure 3.

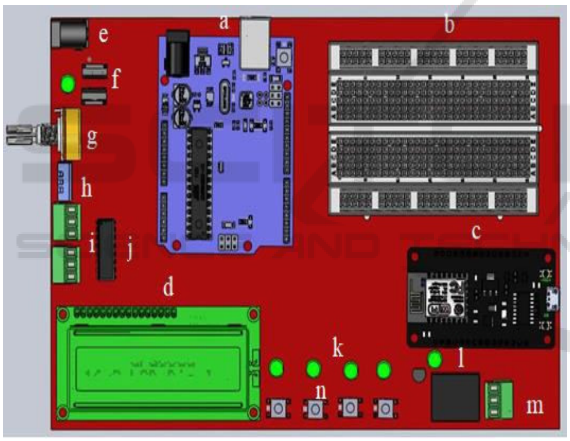

Figure 3: Overall Practicum Module Design.

Caption on picture 3, a) Arduino, b) Bread Board, c) NODEMCU, d) LCD, e) input voltage, f) Regulator (7805), g) Potensiometer, h) DHT11, i) Pin out dc motor, j) IC L293D, k) LED, l) Relay, m) Pin out relay, n) Push button.

3 RESULT AND ANALYSIS

The next step is testing the practical module, this test aims to find out the advantages and disadvantages of the system. The test is carried out in two stages. First, system performance testing and the second overall module testing. The practical module has been made is shown in Figure 4.

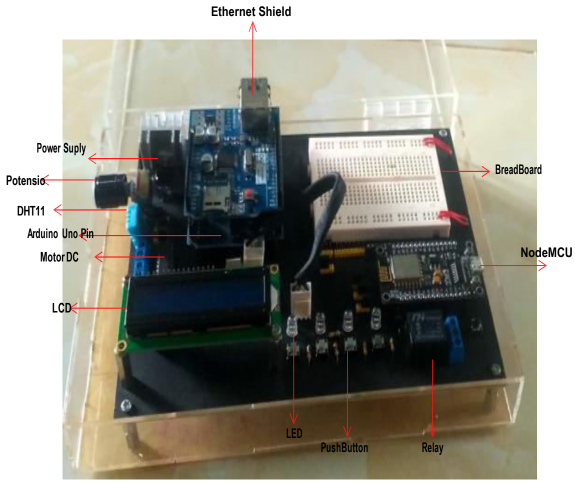

Figure 4: Practical module of embedded systems and data communication.

3.1 Performance Test Modul Embedded System

Tests carried out starting from testing on the embedded system then continued with network data communication. Figures 5a, 5b and 5c are the results of the performance test of the embedded system module which consists of an output, input and Analog Digital Converter (ADC) circuit. The test in this section begins by creating a program to verify that the components in the output section are working properly consisting of LEDs, LCDs, DC motors and servo motors. On the LCD I2C LCD is used, this module is controlled serially in sync with the I2C/IIC protocol (interface). integrated circuit) or TWI (Two Wire interface) with addresses 0x27 and 0x37. To control the DC motor, the motor driver IC L293D is used. The EN1 pin is a pin that is used to enable the DC motor (ON/OFF DC motor), therefore the EN1 pin is connected to the PWM output of the Arduino module. While the IN1 and IN2 pins are used as logic inputs to regulate the rotation of the DC motor and can also be used to quickly stop the DC motor. Control is done by push buttons, keypads and buttons on the browser. The test results can be seen in table 1

Table 1: Motor rotation test.

IN 1	IN 1	Motor Condition
0	0	Stop
0	1	Turn clockwise (CW)
1	0	Turn counterclockwise (CCW)
1	1	Stop

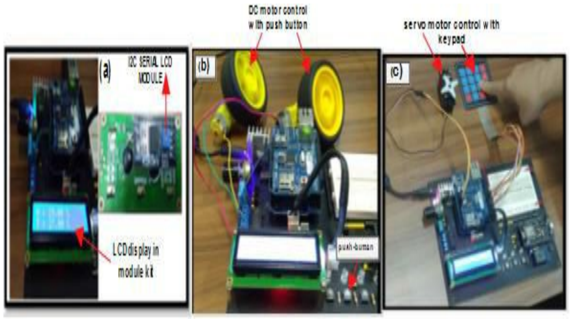

Figure 5: Performance test of the designed module kit: (a) image of LCD display and I2C module LCD; (b) Picture of DC motor control with push button; (c) Picture of servo control with keypad.

The motor rotates clockwise, if the Arduino module pin Pin 9 (IN1) is given a logic low and Pin10 (IN2) is given a logic high and if you want to rotate the other way around then the Arduino module pin Pin 9 (IN1) is given a logic high and Pin 10 (IN2) is given a logic high. low logic. While EN1 is connected to the PWM output of the Arduino module (Pin5). Furthermore, the function test on the input circuit is carried out The 10K resistor functions as an external pull-up resistor at the push button input. With the pull-up resistor, the microcontroller will read logic '1' when no switch is pressed. Without a pull-up resistor, the I/O pin will float and the microcontroller can read it as a logic '1' or '0'. Servo motor with keypad as a control tool to control the servo motor. The program loaded into the embedded system module is when button 2 is pressed the servo motor rotates at position 20º, when button 4 is pressed the servo motor rotates at position 40º, when button 9 is pressed the servo motor rotates at position 90º, and when button 0 is pressed the servo motor rotates at position 0º.

Table 2: Servo Motor Program Logic with Keypad as Control Device.

Keypad	Servo
0	0º
2	20º
4	40º
9	90º

3.2 Performance Test Data Communication Module

Furthermore, testing the module for data communication, the object of this test is to implement temperature monitoring using NodeMCU with a DHT11 sensor. NodeMCU is used as a wireless transmission medium while DHT11 is a temperature and humidity sensor. Testing of objects using a local network to obtain Quality of Service (QOS) results with throughput parameters on the Hypertext Transfer Protocol (HTTP) protocol. The flow of the testing system can be seen in Figure 6.

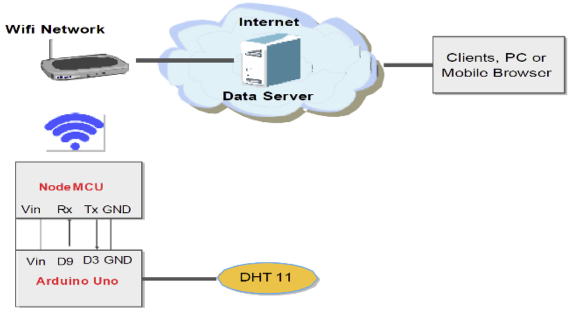

Figure 6: Flow of the http protocol-based data communication module testing system.

The NodeMCU module is a wifi module that is used to connect the microcontroller to the internet. This module is based on the ESP8266 serial WiFi SoC (Single on Chip) with onboard USB to TTL. Pins D5 (GPIO14) and D6 (GPIO12) as RX and TX where RX or Data Receiver is connected to digital pin 9 of the microcontroller, TX pin which is transmitting data is connected to digital 3 microcontroller then GND pin is connected to GND of the microcontroller and VIN pin connected to the Arduino VCC. DHT11 sensor data that has been processed by the microcontroller is sent via wireless. The data is sent with the http protocol using port 80. The data is stored in a database which will then be displayed on a website that is accessed by the user. The results of throughput testing using wireshark can be seen in table 3. Throughput is the effective data transfer rate measured in bps. Throughput is the total number of packets, observed successful packet arrivals during a certain time interval, divided by that time interval (Taruk & Ashari, 2016).

Table 3: Data Throughput.

Package	Average Byte/sec	
	Available throughput	Received throughput
1	1169,887	1165,887
2	1167,889	1160,973
3	1169,949	1168,936
4	1166,954	1160,96
5	1170,883	1169,889
average	1169,1124	1165,329

Based on table 3, it can be seen that throughput is used optimally, the average value of throughput received (1165.329 bps) is close to the overall throughput value (1169.1124 bps). If the percentage is then the throughput value is 99.71%. Throughput data, the network used for testing NodeMCU as a web client with the http protocol is included in the good quality network category based on the reference from the TIPHON table (Wulandari, 2016). Furthermore, observations and testing of the module as a whole are carried out from a series of inputs, outputs, sensors and network-based data communications that are adapted to student practicum jobs, as shown in table 4.

Table 4: Overall Practicum Module Testing Results.

Practical Job	Expected	Observation and testing	Information
Control application with keypad input, push button, sensor	Keypad, push button and sensor can control LED, LCD, dc motor and servo motor	Keypad, push button and sensor can control LED, LCD, dc motor and servo motor	good
LED display application, DC motors, LCD and Servo motors	LED,LCD can be displayed and Servo motor, DC motor can rotate	LED,LCD can be displayed and Servo motor, DC motor can rotate	good
Web-based monitoring system application	NodeMCU and Ethernet can function as a webclient	NodeMCU and Ethernet can function as a webclient	good
Web-based control system application	NodeMCU and Ethernet can function as a server	NodeMCU and Ethernet can function as a server	good

From table 4 it can be seen that the tests were carried out based on student practicum jobs on each input series, and the output results were that all applications tested were successful as expected.

4 CONCLUSIONS

In this study, a simple, inexpensive and portable laboratory kit module was developed for use in embedded systems and communications practicum. Test results DHT 11 temperature sensor can read the index of temperature and humidity whose data is in the form of digital data and displayed on the LCD. The PWM of the DC motor and the direction of rotation of the motor can be controlled using a push button. The keypad can control the direction of rotation of the servo motor so that students are expected to be able to provide authentication through a password with a keypad. Testing the kit module for data communication using a local network to obtain Quality of Service (QOS) results with throughput parameters on the Hypertext Transfer Protocol (HTTP) protocol close to 99.71% include to the category of good quality network. The overall test results are as expected.

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