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Thitisak Aussawarangkul, Saiful Anwar Che Ghani,
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Thitisak Aussawarangkul[1], S.A. Che Ghani[2] , Pakanun Wattanasinbumrung[1] and Worapong Sawangsri[1]

[1] Department of Mechanical Engineering, Faculty of Engineering, Kasetsart University, Bangkok, 10900, Thailand
[2] Faculty of Mechanical Engineering, Universiti Malaysia Pahang, Pekan, Pahang 26600, Malaysia
`fengwps@ku.ac.th`

Abstract. Nowadays, automation system is necessary in every warehouse. It can assist operators in easily managing warehouses furthermore reduce unexpected errors from humans and surrounding environments. Nevertheless, a number of control methods have been available for the warehouse system. Each method has advantages and disadvantages considered regarding ease of use, stability as well as cost-effectiveness, etc. Therefore, in order for comparative performances of control algorithms between the PLC and the Arduino, the models of automatic warehouse with PLC and Arduino boards are implemented in this paper. The comparative results show that the average time difference between two methods is 7% with Arduino being faster and lower cost rather than PLC. This ability of using microprocessor as the Arduino board presents some advantages even lesser stability. Thus, alternative methods with current and higher technological devices are possibly selected instead of the old-fashion control algorithm in order to gain more benefits and advantages. Furthermore, integration of the ROS with an automation unit to upgrade an existing system have currently been conducted on the warehouse system to evaluate and compare the system's performances. The results will be presented in a separated paper.

Keywords: Warehouse Robot, Arduino Processor Robot, PLC Processor Robot.

1   Introduction

Currently, part and spare parts are increasing due to the high demand market. Manufacturers have stocked those parts in warehouses to protect uncertain manufacturing processes of goods as well as sufficient supply to mass production. It is necessary to sort them out by type to make it easy to find and pick them up and save space for store workpieces. Lots of warehouses solve these problems by making vertical stores [1]. However, whenever storage is much higher from the floor, it is difficult to retrieve and store workpieces. Automatic robots and currently high technological devices are able

to assist in every situation which makes tasks possibly handy and reduces accidents from high falls [2].

Thus, the 3-axis Cartesian robot is used to conduct the automatic warehouse system [3-4]. This robot has been selected in this study due to not having a revolute joint, thus do not be concerned about the orientation of products. The system is performed with two comparative control methods namely included the PLC (programmable logic controller) and the Arduino. Therefore, the system performances have been evaluated and discussed on whether advantages or disadvantages.

PLC is one device that is easy to understand and common use in industry and daily life, e.g., traffic signals in every intersection that we pass every day using a PLC controller. Nowadays, traffic signals can detect emergency vehicles and dynamically manage the traffic light to facilitate and let them pass first [5]. This presents an effective, reliable, and stable PLC exchanging with a relatively high price.

Arduino is especially popular in education on automatic control or robotics [6] because of its cost-effectiveness and ease of programming with a lot of Arduino libraries [7]. The Arduino dataset contains more features than the PLC data set such as Functions, Comments, Lines of code, etc. [8]. In addition, the operated time comparison is appropriate for considering robot performance assessments. For example, Stephanie Glass et al [9] presented the compared operative time between conventional laparoscopy and robotic-assisted Sacrocolpopexy. Therefore, a comparative study to investigate the performances of control algorithms between the PLC and the Arduino by considering the operating time as the primary parameter to compare between two control methods is conducted in this paper.

2 Experiment Implementations

2.1 Demo Warehouse

**Fig. 1.** Warehouse demonstration structural design

The demonstrated warehouse is constructed by aluminum profile 2020 V-slot and aluminum profile 2040 V-slot for robot guideway and steel angle bar for storage structure. Storage structure is built with up to three floors and four slots per floor that can place workpieces as shown in Figure 2. Dimensions for each slot are 100 mm height × 180 mm width and palate size 800 mm × 90 mm, respectively.

		4	3	2	1
		8	7	6	5
		12	11	10	9
Store Slot	Retrieve Slot				

Fig. 2. Diagram shows location of each slot

**Fig. 3.** Cartesian Robot Structure
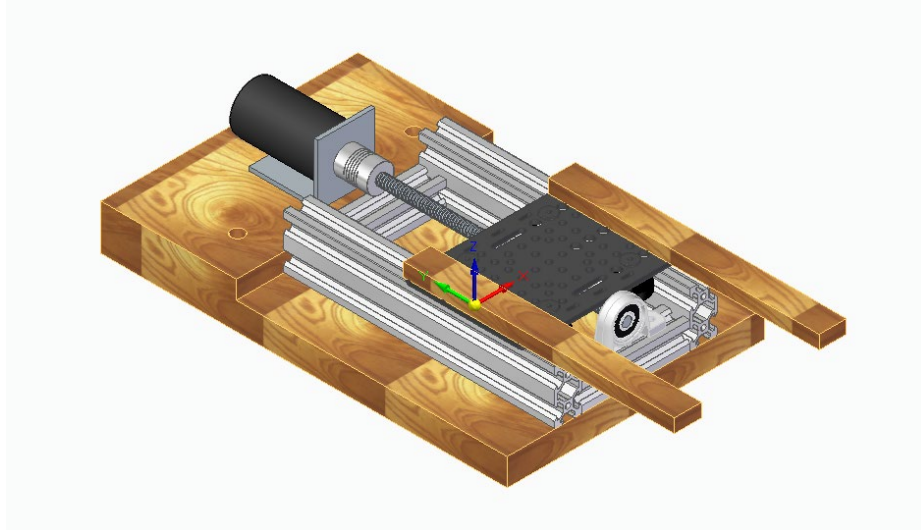
Fig. 4. The slider Design with linear actuator

The slider is designed shapely like a forklift using a lead screw to retrieve or store pallets at desired slot, presented in Figure 4.

2.2   PLC Ladder Diagram Programming

The IEC- 1131-3 is commonly use as a standard programming language for PLC [10-11]. It consists of two textual languages, instruction list, and structured text, as well as two graphical languages, Ladder Diagram and Function Block Diagram, respectively. The PLC Delta AS332T from Delta Electronic is applied for control robot and build ladder diagram by the ISP Soft software. This is Delta's freeware that only works with Delta's device. Ethernet cables are used for communication between a PLC device and a computer. The main functions that control motors used in the ladder diagram are Absolute position control (DDRVA), Relative position control (DDRVI), and zero return (DZRN), respectively.
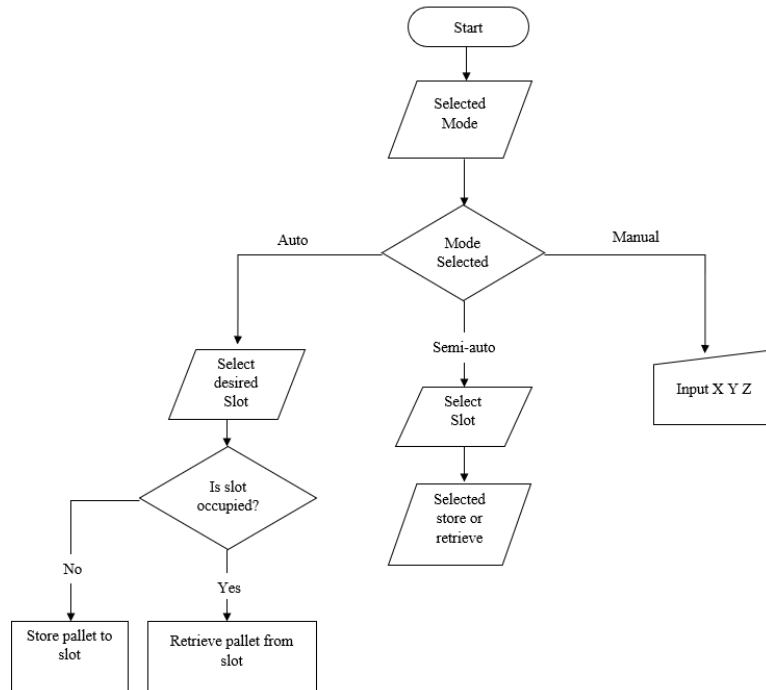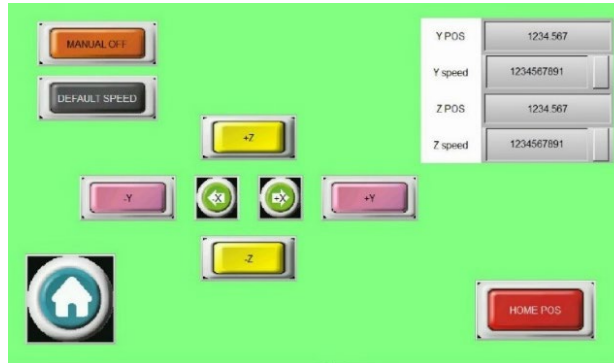
Fig. 5. PLC programming workflow diagram of 3 modes

2.3   HMI Programming

The User Interface is created for HMI (human machine interface) by DOPSoft Delta's freeware program. HMI is commonly used for input from human and sent to PLC with IP address configuration.
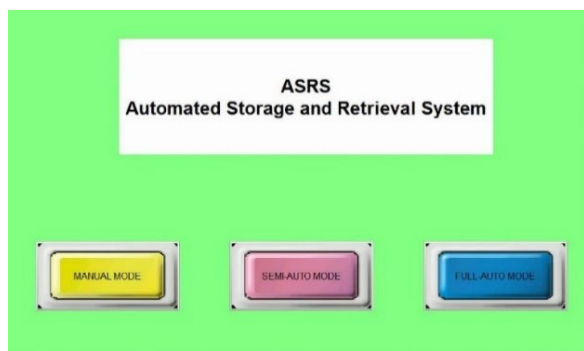
Fig. 6. Display screen of HMI, users have to select desired modes to work Manual, Semi-Auto, or Full Auto.

Fig. 7. Manual Mode, users can manually control position of X, Y, Z and speed of robot via HMI screen.

Fig. 8. Semi-Auto Mode, users can select the desired slot and choose to store or retrieve pallet.

Fig. 9. Full Auto Mode, users only selected the desired slot and the system will operate every step.

The developed system has three control modes can be selected. Full Auto, Semi-Auto and Manual. Full Auto mode, users only select the desired slot for placing a workpiece,

then the system will automatically operate every step. Where the system is recognizing that in that slot have any workpiece. If not, it will store new one. But if there is, it will be pick up that workpiece at that slot. Semi-Auto mode is for specific control of picking or storing and selecting desired slots. Furthermore, if users need to control any other movements of the robot, use the manual mode.

2.4 Arduino Programming

Besides the PLC, the Arduino board is a microcontroller for robot control. The Arduino Mega2560 has been selected for system control purposes. It has 54 Digital IO and PWM (Pulse Width Modulation) output mode that can control motor. C language and libraries are known as Arduino IDE which open-source programing is implemented for the system control algorithms. It contains various codes in libraries and also has a community helping with coding developments to support a variety of devices. Therefore, it is another option for deciding to choose Arduino as part of this research.
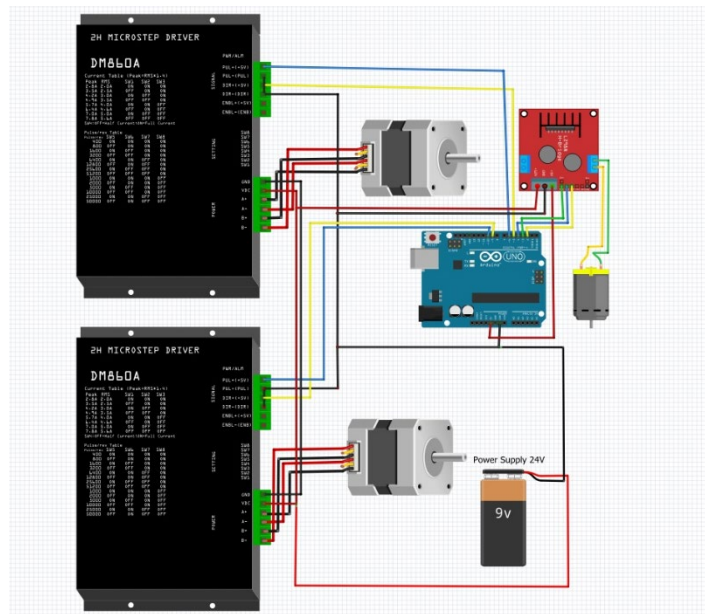

Fig. 10. Schematic wiring of Arduino

3 Results

In experimental results. Time intervals from the initial station to each slot are collected and compared between two different control methods presented in Figure 11. The average time spent on both control algorithms is not much different (7% difference) where Arduino is faster than PLC.

TIME FROM IDLE TO SLOT

◆ TimeArduino ■ TimePLC
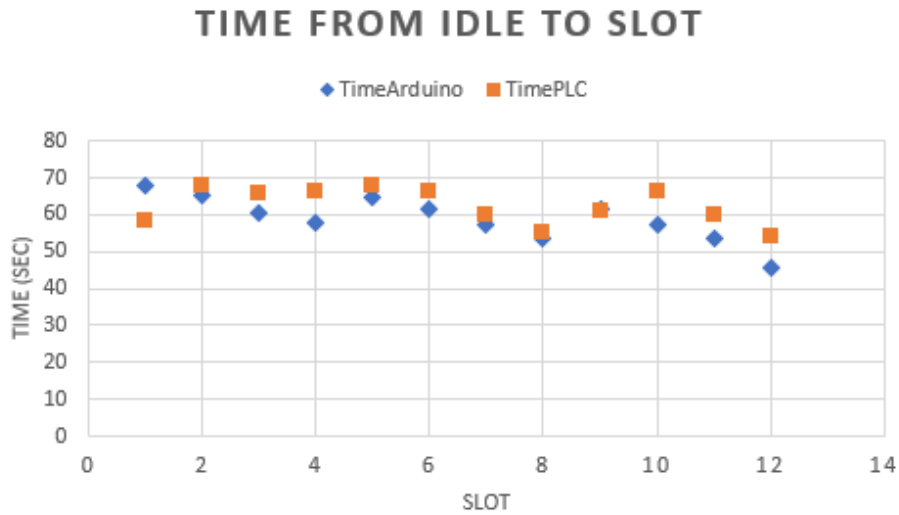
Fig. 11. Time intervals from the initial station to each slot

After collection of time intervals moving the object from the station to storing slot and vice versa as well as the average time of two modes. Thus, the power consumption of both methods is monitored.

ENERGY CONSUMPTION

◆ Delta's PLC ■ Delta's PLC+HMI ▲ Arduino MEGA 2560
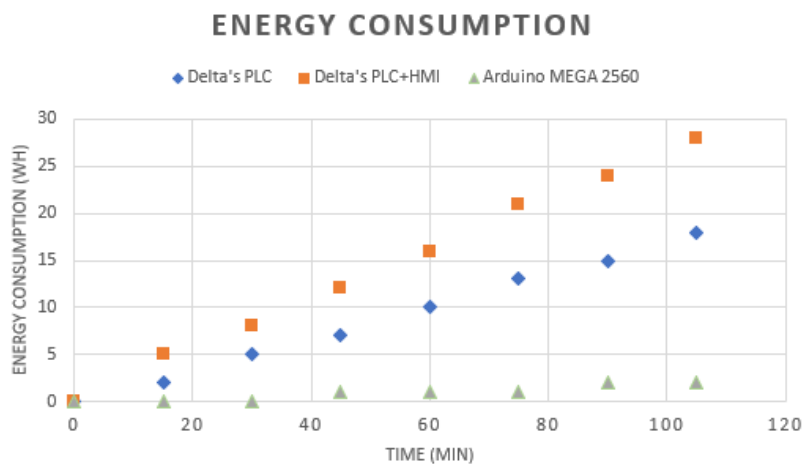
Fig. 12. Energy consumption of a) Delta's PLC b) Delta's PLC with HMI and c) Arduino MEGA 2560

From fig.12 shows the energy consumption of PLC with HMI consumes more power than Arduino MEGA 2560 around 173.33% without connecting any device to PLC or Arduino.
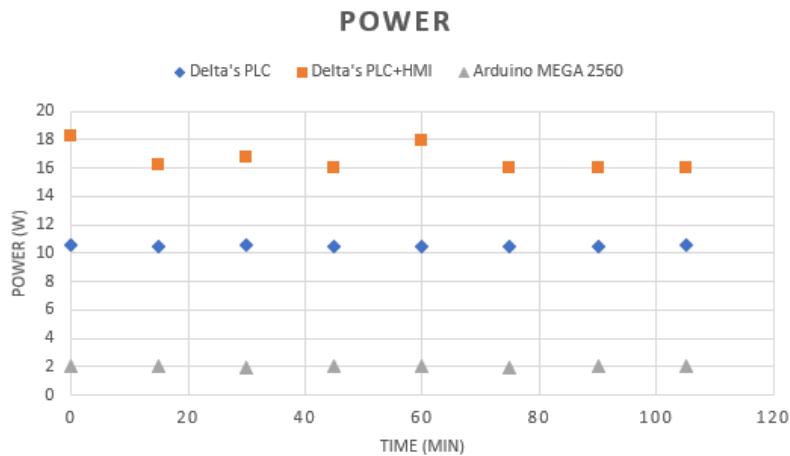
POWER

Fig. 13. Power of each device a) Delta's PLC b) Delta's PLC with HMI and c) Arduino MEGA 2560

The results presented regarding energy consumption, Arduino consumed power of around 2 watts while PLC with HMI used the power of around 18 watts, and standalone PLC is around 10 watts. This huge difference obviously illustrates why the PLC needs 24V power supply while the Arduino only uses 5V.

4   Conclusion

The comparative control methods to manipulate the demonstration of the automatic warehouse system are implemented. This comparative study presented results of PLC and Arduino are very close and going in the similar direction in overall aspects. However, programming language and structure including sequences of both methods might affect system running speed, if written in a concise structure, it might make the system faster.

Arduino has an advantage in less power consumption and the I/O pin can be program flexible to connect a variety of sensors but it requires expert programmers in c or c# languages. Meanwhile, PLC is often implemented at industrial level rather than Arduino due to reliability and has more industrial application connection protocols, and is rugged. Also, HMI is required if user want to manually control directly to PLC.

In experimental implementations, it can be seen that whatever is microprocessor can be applied to an automated robot system. It depends on which systems will be picked up and integrated into the devices. Recently, the ROS system is quite interesting and

suitable for programming to work with automated robot systems. Thus, an automatic warehouse system has currently been conducted by using ROS, and implemented results will be reported in the near future.

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