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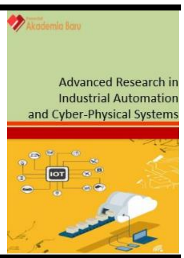

Integration of an Automated Guided Vehicle System with a Programmable Logic Controlled Material Handling

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ABSTRACT

In industry, material handling involves the movement, protection, storage and control of materials and products throughout manufacturing, warehousing, distribution, disposal process and energy consumption of a manufacturing system. However, synchronization and integration of the system between all machine in the material handling processes cannot be performed automatically out of the box. Communication between all of the different machine presents a challenge when the integration of material handling system was to be performed. The purpose of this project is to verify and establish a connection between an Automated Guided Vehicle (AGV) and a Programmable Logic Controller (PLC) of a material handling system to directly or indirectly improve the productivity and efficiency of the overall system. It focuses on the connection between the Pioneer 3-AT AGV and Omron CP1L PLC by using C++ language. The C++ language can be acknowledged as one of the most widely used programming languages and thus could provide some common platform for all the different material handling machine to communicate to each other. The Pioneer 3-AT AGV was programmed in C++ through the Advanced Robotics Interface for Application (ARIA) library available from the AGV manufacturer. The Omron PLC which was attached to a conveyor system representing the material handling system was connected to an OLE for Process Control (OPC) before communication between the PLC and AGV can be performed. At the end of the project, the communication between the PLC and AGV was established and the integration capability between AGV and PLC was verified.

Keywords:
Integration, Automated Guided Vehicle, Programmable Logic, Material Handling

1. Introduction

Manufacturing industry plays an important role and made a large influence in the economic growth. Today, plants and machines must reach increasingly higher rates of productivity and efficiency at the lowest possible cost. At the same time, the next stage of industrial manufacturing is

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already looming on the horizon: Industry 4.0, characterized by smart factories and self-organizing communities of machines driven by information generated in the virtual world. Meanwhile, the manufacturing industry facing more challenges to get prepared for the new technology of digitalization in future, as the integration system will be one of the most important fundamental [1], [2]. Therefore, the manufacturing industry is always searching for improvement. To improve it directly or indirectly, one of the methods is to integrate the system to increase the productivity. There are a lot of systems in manufacturing industries such as material handling system, packaging system, and fabrication system [3, 4].

Material handling system involves short distance movement within the confines of a building or between a building and a transportation vehicle. It utilizes a wide range of manual, semi-automated, and fully automated equipment and included consideration of the protection, storage, and control of material throughout their manufacturing, warehousing, distribution, consumption, and disposal process [5]. In a simple way of explanation, material handling system is a system concerned about loading, moving and unloading of materials. Some examples of the material handling system are Automated Guided Vehicle (AGV) system and conveyor system.

AGVs is a flexible manufacturing system [6]. This system can improve response time for material movement due to its sustainability for long and short distance move [7]. There are a lot of industries choosing AGVs as material handling system [8]. The example of AGV are towing AGV, unit-load AGV, pallet truck AGV, and fork truck AGV [8].

Conveyor systems are especially useful in the application involving the transportation of heavy or bulky materials. Conveyor systems allow quick and efficient transportation for a wide variety of materials which make them very popular in the material handling and packaging industries [1]. There is a positive growth for conveyor system on manufacturing industry. The example of the conveyor system likes pneumatic conveyor, vibrating conveyor, flexible conveyor, vertical conveyor and others. There are many conveyor systems is using Programmable Logic Controller (PLC) to control it.

PLC is an industrial digital computer which is flexible, ruggedized and adapted for the control of manufacturing processes, such as assembly lines, or robotic devices, or any activity that requires high-reliability control and ease of the programming and process fault diagnosis [5]. By using the PLC, the output results must be produced in response to input conditions within a limited time.

In future, the material movement should be fully integrated to form a coordinated, operational system which including receiving, inspection, storage, production, assembly, packaging, unitizing, order selection, shipping, transportation and the handling of return [5].

Currently, the problem facing by manufacturing industry is most products or materials transfer manually with or without the help of a machine. Human guidance is needed to transfer material or product from point A to point B. Even they use AGV, the human operator still needed for tasks like loading or unloading which are difficult to fully automate. To avoid non-value added activity, integration between systems is beneficial. Besides that, the whole system in the manufacturing industry is not synchronized without integration between all machines system.

The proposed project is to establish communication between AGV and controller of material handling system, in this case, using PLC. The research starts from integrating the AGV and PLC material handling system. A scenario is designed to test and verified the establishment of the communication. The objective of this paper is to establish communication between AGV and PLC conveyor system and verify the integration capability.

2. Methodology

In the project, the preferred method of communication between the AGV and the PLC was through Wi-fi or LAN network [10, 11]. Therefore, the preferred communication protocol will be the Transmission Control Protocol/Internet Protocol (TCP/IP). Once communication protocol was established a program that allows data transmission between the AGV and PLC program using the C++ language. However, performing a direct communication between PLC and the AGV was costly due to additional expensive network module that needs to be added to the PLC hardware. Thus, to counter the problem a host computer (PC) was connected to the PLC through a physical LAN cable to permit the PLC to communicate with the AGV through the TCP/IP protocol. The host computer was already equipped with a Wi-Fi connection and thus provide a type of bridging connection between the AGV and the PLC through the Wi-Fi and LAN connectivity. An OPC server was used to enable the PLC to communicate with the host computer through a specific design C++ program. The program will also manage communication receive and send to the AGV. Another program design in the AGV onboard computer using C++ will manage communication from and to the PLC host computer.

2.1 Software and programming

There are a few software's that were needed when integrating between the AGVs and the host computer. The software includes ARIA (Advanced Robotics Interface for Applications), Mobile Eyes, Mobile Sim and Mapper3 Basic. ARIA provides an interface and framework for controlling and receiving data from AGV as well as sensors and other accessory devices. This all is a simple and single C++ library. It includes writing robot control software and tools for writing cross-platform. In a simple way to say, ARIA is a library that contains a lot of software that helps the AGV. Mobile Eyes is a software to remote user interface application for control, visualization, monitoring, and configuration. It can help to find out the position of the AGV, sensor data, sending commands and changing configuration variable in real time. It also can send custom commands and view the custom graphics of the map and AGV display. Mobile Sim is a simulator that uses with ARIA or other compatible software that supports mobile robot platform. It provides a simulated control connection accessible via a TCP port. Then, ARIA will automatically connect to the TCP port, making the same programs using the simulator but the real robot will not affect anything. Mapper3 Basic is a navigation software used for creating and editing maps for robot operating environment. It is used in the Mobile Sim or other software using the ARIA library. It can generate a map from the laser scan and add goals and others object such as obstacles. The software needs to communicate the PLCs and the host computer are CX-One, QuickOPC, MatrikonOPC server for Omron PLC and MatrikonOPC Explorer. CX-One allows users to build, configure and program a host of devices.

2.2 Development of Communication System

The communication between AGV and host computer is established via WLAN connection. The host computer is used WLAN to connect to the AGV. Pioneer 3 AGV is an AGV with the onboard computer. So, to connect it with the host computer with the wireless Ethernet can using a PC-104 card to connect the onboard computer inside the AGV. Then, the AGV can existing Wi-Fi or an access point provided by itself. For the communication between PLCs and host computer, PLCs use USB for the peripheral port. So, the host computer can connect it using normal USB cables or Ethernet cable and without others special cables. Then, the PLCs control the conveyor system through the router to the pulse output or driver.

2.3 Data Transfer

Figure 1 shows that the data transfer from AGVs to host computer. The experiment starts from programs the AGV and makes AGV start moving. The AGV will move to set location and stop awhile. Then, the AGV will move back the original location. When the AGV moving back to the original place, the AGV will stop and send the signal to the host computer by using the WLAN. After the host computer receives the signal from AGV, it will send a signal to PLC conveyor system. Since the project is two-way communication, so after state how the AGVs transfer data to PLC conveyor system, now we start with PLC conveyor system transfer data to AGVs

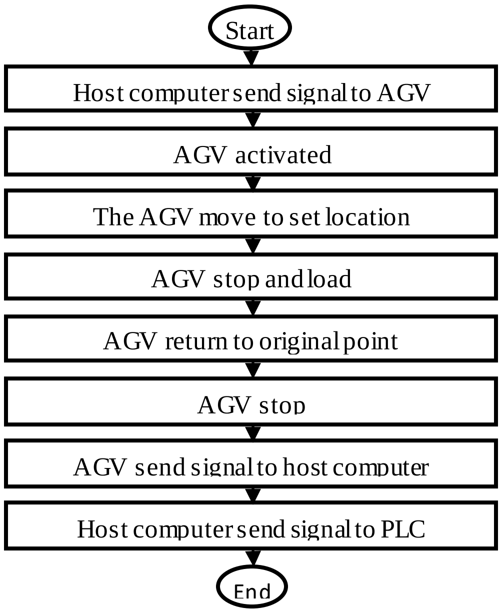

Fig. 1. Data transfer from AGVs to host computer

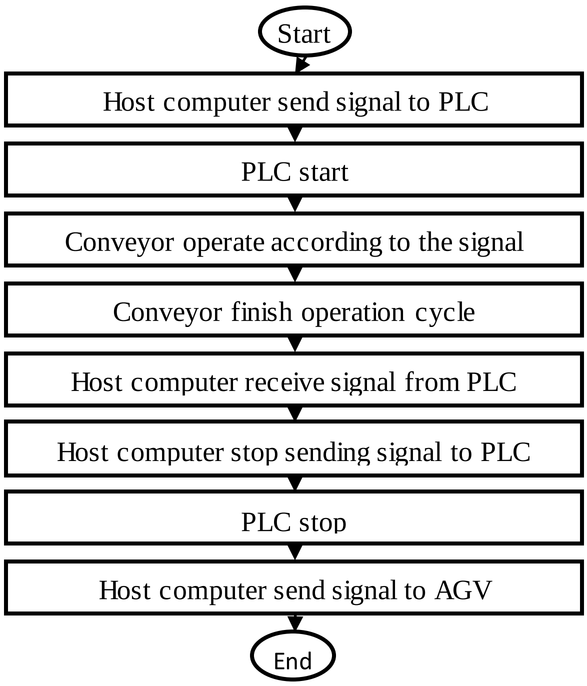

Fig. 2. UTM-LST delta wing VFE-2 profiles

Figure 2 is the data transfer from PLC conveyor system to AGVs. The experiment starts with PLC control the conveyor moving by control the motor driver. The conveyor moves accordingly the programming set by the host computer. When the conveyor finishes a cycle, the PLC will send a signal to the host computer via LAN cable. The host computer will stop sending a signal to PLC. After conveyor system is stopped, the host computer will send a command to activate AGV system.

3. Results and Discussion

3.1 Validation

There are a lot of connection might be able to connect the both AGV and PLC system. Therefore, there are few connections are tested to connect the systems and below the validation table is the result of the test. The reason of failure to connect is due to lack of knowledge of C++ programming language.

Table 1
Validation Table for the coding

No	Category	Information Detail	Result	Problem
1	CMD-AGV	Using command prompt connect the AGV.	Fail	Command prompt has a lot of limitation like cannot store the Aria library.
2	Phyton-AGV	Using Phyton language to connect the AGV.	Fail	Lack of knowledge of Phyton language.
3	Linux-AGV	Using Linux OS as interface and connect the AGV.	Fail	Facing the same problem with command prompt cannot store the Aria library
4	C++-AGV	Using C++ language connect the AGV.	Success	-
5	C++-CX programmer	Using C++ language connect to CX programmer.	Fail	Difficult to connect the CX programmer without the CX compiler.
6	C++-Arduino	Using C++ language connect to Arduino and using Arduino connect the PLC.	Fail	Arduino becoming the core to control the conveyor system. It can function without PLC system. Out of topic.
7	C#-OPC	Using C# language connect to OPC server and then connect to the PLC.	Fail	Lack of knowledge of C#.
8	C++-OPC	Using C++ language connect to OPC server and then connect to the PLC.	Success	-
9	Connect both systems	Using C++ as medium interface and connect both systems.	Success	-

Table 1 shows that the validate table for this project. After few experiments, the results show that C++ language able to connect to both systems. Therefore, this project used C++ software as an interface to connect both AGV and PLC.

3.2 Connection of the complete system

The connection between AGV system and PLC system is through a C++ program and OPC [11] as medium interface and call out each other when need. Figure 3 shows the relationship between C++ software with AGV and PLC system. First, the main C++ coding will call out the PLC coding. Then the PLC coding will debug and connect to the MatrikonOPC Server. After that, the MatrikonOPC Server will send a signal to Omron PLC to actuate the conveyor. After the PLC coding is done it job, the main C++ coding will call out the AGV coding and debug it to connect to the MobileSim. The AGV will move according to the coding set. After the AGV coding debugs finish, the main C++ coding will call out the PLC coding and debug again.

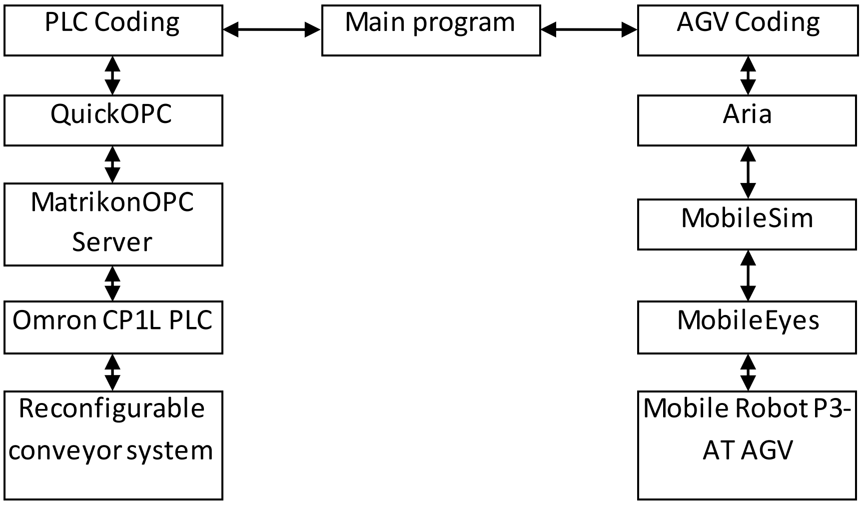

Fig. 3. C++ program link with AGV and PLC system

AGV coding was made by including the header file of Aria into AGV coding. A map was drawn in MobileSim and loaded to a mobile robot. A coding was created in C++ to control the movement of the robot. To connect the mobile robot with PLC coding, Virtual Network Computing (VNC) was used to connect the mobile robot with C++ program and Sonar localization (SONARNL) was used as the technique for localization of the mobile robot. MobileSim was used to simulate the mobile robot first before connecting the mobile robot through the MobileEyes to move the mobile robot.

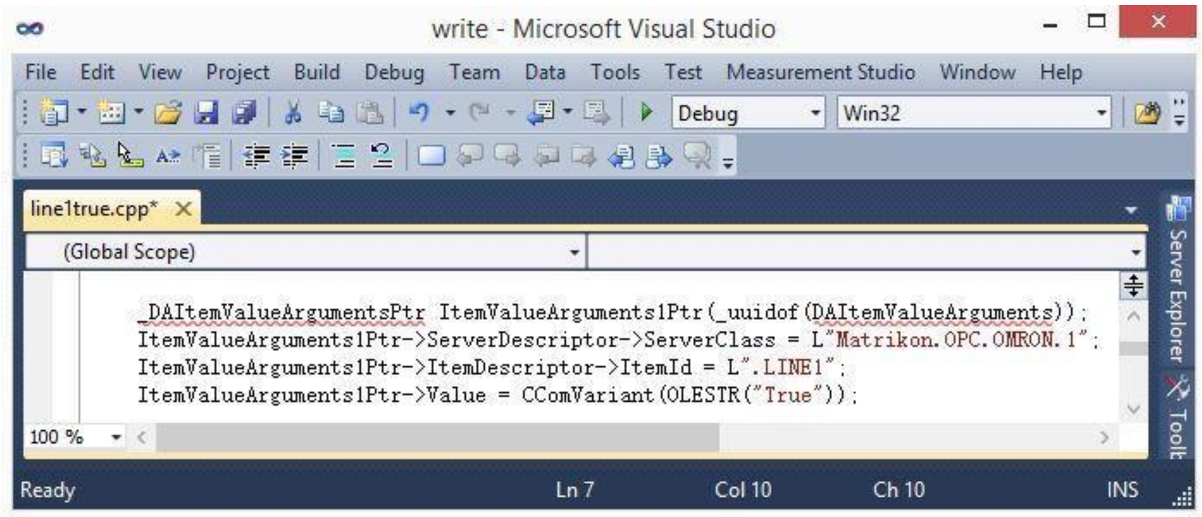

Fig. 4. The coding that energize the value (to become true)

The connection of C++ program with OPC was through the QuickOPC. In the PLC coding, the header file of the QuickOPC was included. QuickOPC was used to connect PLC coding with other OPC software. The connection can be made by selecting the right server class of the OPC which in this case the server class of MatrikonOPC server is “Matrikon.OPC.OMRON.1”. Some data on the

MatrikonOPC can be written or read. To write the data onto MatrikonOPC, the set of data, server class, item id and data needs to be declared in the PLC coding as figure 4. Item id is the address of data that want to be changed in the PLC. To read the data on MatrikonOPC, the set of data, server class and item id need to be declared in the PLC coding. The connection between MatrikonOPC servers can be made in the server configuration of MatrikonOPC. The PLC act as the client of the MatrikonOPC and the item id can be view and monitor via MatrikonOPC explorer.

3.3 Scenario for verification

A scenario is designed for this project. The proposed is used to show the communication between AGV and PLC through simulation. Figure 5 shows that the scenario for verification. The system starts with PLC system. Line 1 starts while others line is stopped. After 3 seconds, LINE 2 is starts and LINE 1, LINE 3 and LINE 4 is stopped. LINE 3 and LINE 4 is continued after the LINE 2 stop running. After the LINE 4 finish run, the PLC system will stop and the AGV system will start after 5 seconds. The AGV will move until certain position and then move back to the original place. Then, the PLC will be repeated the same movement start with LINE 1.

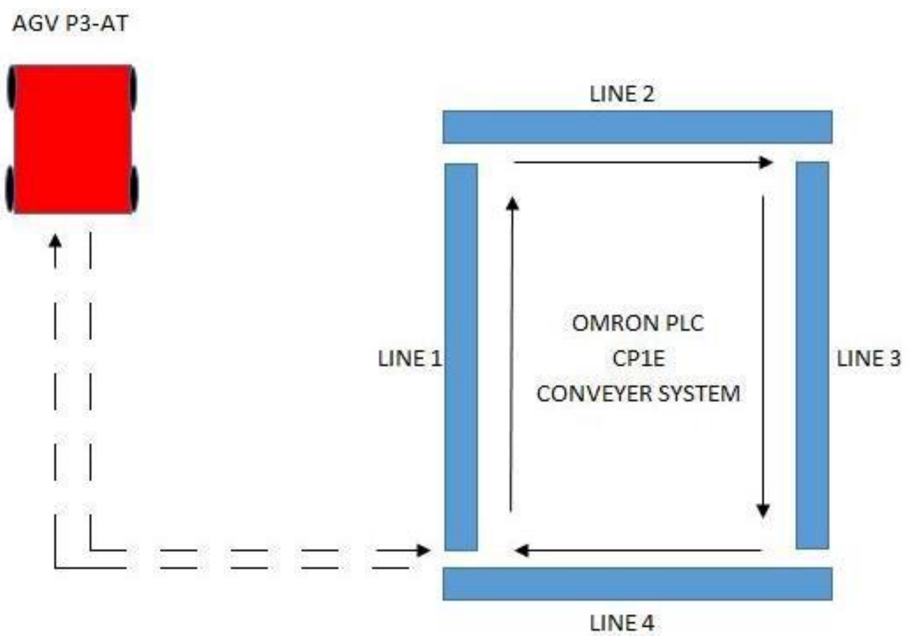

Fig. 5. The verification scenario

The full results are done using simulation. First, the main coding called out the PLC write coding. Then, the PLC coding connected to the MatrikonOPC Server to write data value and the result can be shown in MatrikonOPC Explorer. After the PLC write coding finished a cycle, the main coding called out the PLC read coding and read the data value from MatrikonOPC Explorer through MatrikonOPC Server. Then, the main coding called out the AGV coding. The AGV coding will connect to the MobileSim and started to control AGV move. After the AGV move back to the original position, the main coding called out the PLC write coding and continued the loop.

From the result, the AGV able to follow the instruction sent from AGV coding. The velocity, angle of rotation, and the time of the AGV can be controlled and there is no any delay when debugging. For the PLC part, the PLC able to read data from MatrikonOPC Server and write data to MatrikonOPC Server directly without any delay. Besides, the MatrikonOPC Server also able receive the data directly and change the data value of MatrikonOPC Explorer. As a result, the simulation to verify the communication between AGV and PLC is very smoothly without any delay problem. The full process able to complete in 3 minutes starts from PLC to AGV and AGV back to PLC.

4. Conclusions

In conclusion, the P3-AT mobile robot and Omron CP1L PLC able to communicate by using C++ language. The C++ coding able to connect and control the P3- AT mobile robot to move forward, reverse, rotate and move autonomously. Besides, the C++ coding able to read the data from PLC and write data to PLC. From the scenario, the P3-AT mobile robot is able to start to function after the Omron CP1L PLC is stopped function. In reverse, the Omron CP1L PLC are also able to start function after the P3-AT mobile robot moving back to the original position and stop functioning. This shows that the P3-AT mobile robot able to integrate with the Omron CP1L PLC. As a result, the communication between AGV and PLC conveyor system was established using communication system as discussed in section 2.2. Besides, the result also verified the integration capability between AGV and PLC conveyor system through experimentation.

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References

[1] Yee, O.F. (2015). “Development of A Concept for Physical Reconfigurable Conveyor System,” B. Eng. Dept. Robotics and Automation, Fac. Manufacturing Eng. Univ. Teknikal Malaysia Melaka, Malaysia.
[2] Azwan, M. Sc B. Eng Azrul, and Abdul Rahman. "Approach for integrating predictive-reactive job shop scheduling with PLC-controlled material flow." (2013).
[3] Kajan, Martin, Leo Mrafko, František Duchoň, Peter Hubinský, and Ján Šovčfík. "Control of automated guided vehicle with PLC SIMATIC ET200S CPU." *American Journal of Mechanical Engineering* 1, no. 7 (2013): 343-348.
[4] Jaiganesh, Venu, J. Dhileep Kumar, and J. Girijadevi. "Automated guided vehicle with robotic logistics system." *Procedia Engineering* 97 (2014): 2011-2021.
[5] Aized, Tauseef. "Material Handling in Flexible Manufacturing System." In *Future Manufacturing Systems*. IntechOpen, 2010.
[6] Butdee, Suthep, Anan Suebsomran, Frederic Vignot, and Prasad K. Yarlagadda. "Control and path prediction of an Automate Guided Vehicle." (2008).
[7] Hollier, Robert H. *Automated guided vehicle systems*. Springer Verlag, 1987.
[8] Wu, Xing, Peihuang Lou, Qixiang Cai, and Chidong Zhou. "Design and control of material transport system for automated guided vehicle." In *Proceedings of 2012 UKACC International Conference on Control*, pp. 765-770. IEEE, 2012.
[9] Chu, Julio, and James M. Luckring. *Experimental surface pressure data obtained on 65 delta wing across Reynolds number and Mach number ranges*. National Aeronautics and Space Administration, Langley Research Center, 1996.
[10] Kongezos, Valentinos K., and Charles R. Allen. "Wireless communication between AGVs (autonomous guided vehicles) and the industrial network CAN (controller area network)." In *Proceedings 2002 IEEE International Conference on Robotics and Automation (Cat. No. 02CH37292)*, vol. 1, pp. 434-437. IEEE, 2002.
[11] Lindsay, Craig, Glen Bright, and Maceij Hippner. "Advanced material handling system for computer integrated manufacturing." *Robotics and Computer-Integrated Manufacturing* 16, no. 6 (2000): 437-441.
[12] Mahmoud, Magdi S., Muhammad Sabih, and Moustafa Elshafei. "Using OPC technology to support the study of advanced process control." *ISA transactions* 55 (2015): 155-167.