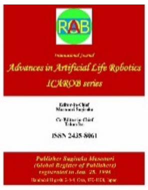
SUGISAKA MASANORI

Journal of Advances in Artificial Life Robotics
Vol. 1(3); December (2020), pp. 116–121
ON LINE ISSN 2435-8061; ISSN-L 2435-8061
https://alife-robotics.org/jallr.html



Research Article

AGVs Task Management with Occupancy Grid Map for Foam-Manufacturing In-Plant Transport

Amornphun Phunopas[1], Wisanu Jitviriya[1], Noppadol Pudchuen[1], Songklod Tunsiri[2], Eiji Hayashi[3]
[1]*Faculty of Engineering, King Mongkut's University of Technology North Bangkok, 1518 Pracharat 1 Road, Bangsue, Bangkok 10800, Thailand*
[2]*Urban Community Development College, Navamindradhiraj University, Wachira Phayaban, Khao Road, Dusit, Bangkok 10300, Thailand*
[3]*Computer Science and Systems Engineering, Kyushu Institute of Technology, 680-4 Kawazu, Iizuka, Fukuoka 820-0067, Japan*

ARTICLE INFO

Article History

Received 11 November 2019
Accepted 10 August 2020

Keywords

Automated tasking
AGVs traffic and queue management

ABSTRACT

AGVs are increasingly used in the automated warehouse with a high demand for changing traditional workflow management to industrial 4.0. The heart of the computerized system is the central software that can distribute work functions from the queues and manage the AGVs' traffic. On the 2D floor plant layout and the occupancy grid map, the RFID girds are initially from marked points or the place that AGVs have to transit to do an assigned task. This research proposes autonomously generating paths via four nearest grids and path switching scenarios. The results show the generated paths with sequential tasks concurrently in random conditions. The task management method can prevent the AGVs' crash and bottleneck from the operation of nine machines in the foam manufacturing plant.

1. Introduction

Nowadays, automated warehouses are widely used in the industry. One example is the IPIN competition. It challenges the problem of position-tracking in the indoor environment, which is the initial scenario that industry needs. The industrial mobile robots or AGVs have to track the magnetic path in a closed route under the defined trajectory [1]. The system consists of many modules of software and hardware, for example, the central computing unit, the fixed automation unit, and the movable agent. These AGVs are one part of the system that complies with the assigned tasks sequentially. They can move to the target and do an assigned task; when it finishes a task, it then moves to the next position according to the production process. Moreover, this implemented technology is suitable for a different industry that has to compromise with the investor on factors of break-even point and payback period. The central software is the key to success in optimized productivity. This paper proposes a scenario that progresses previous work in using AGVs in foam a manufacturing plant [2]. The central software manages tasks in the queue and assigns them to two AGVs, then tests this in the real plant. Moreover, the knowledge about indoor autonomous robots that was gained over many years in the World RoboCup Rescue League helped create an occupancy grid map of the plant layout [3]. The map is beneficial for scenario simulations and software development.

2. System Overview

Corresponding author's E-mail: amornphun.p@eng.kmutnb.ac.th, wisanu.j@eng.kmutnb.ac.th URL: https://iraps.eng.kmutnb.ac.th

The plant layout is created from part of the foam manufacturing process. The foam product must be transferred from the front machine to the hot temperature room to drain the humidity—the AGVs work in zone 1, zone 2, and zone 3. Completing the primary task takes a full cart from zone 2 to zone 3; then, the secondary task takes an empty cart from zone 1 to replace the taken full cart in the front machine. The AGVs can travel via all grids, which are connected as a path. It takes a series of grids from the current position to any destination in the plant layout in Fig. 1. The path is generated from the central software by traffic management to make the AGV pause or generate a new path that can avoid the collision to another AGV.

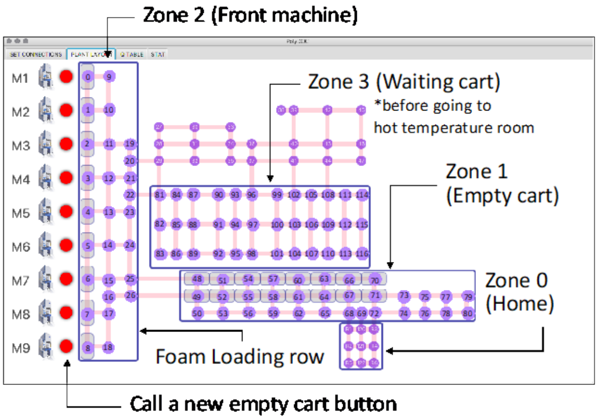


Fig. 1 Plant layout with four nearest grids and guided lines.

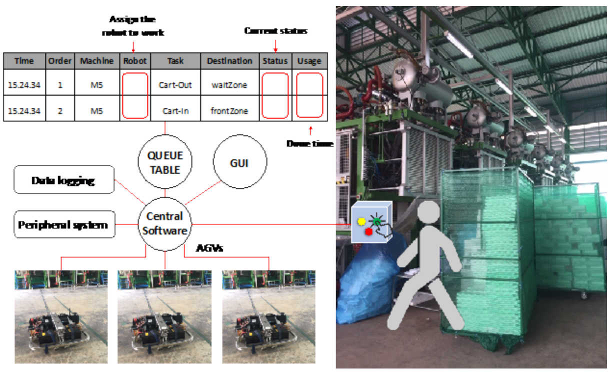


Fig. 2 The worker loads the foam product to the empty cart. When the cart is full, the worker will press the button. The central software pools the information and manages the tasks.

The system consists of the central software, pushbuttons, and AGVs. The operation starts from the worker pressing the button in front of nine machines, randomly depending on putting the foam to the cart finish in Fig. 2. Then, the central software will add the number of the front machine into the queue table. If there is an AGV available, it will be assigned to the queue and instantly start doing the assigned task. Thus, there are two sequential queues in the queue table meant to complete the cart-out and cart-in task.

3. Automated Task

The central software will provide the job that the AGVs have to do. The concept is that an AGV goes, arrives at a target, and performs a job until the last subtask. The AGV always communicates with the central software and is then assigned to the next target and do the next job. After finishing the task, the AGV is free and prompt to receive a command from the central software in Fig. 3.

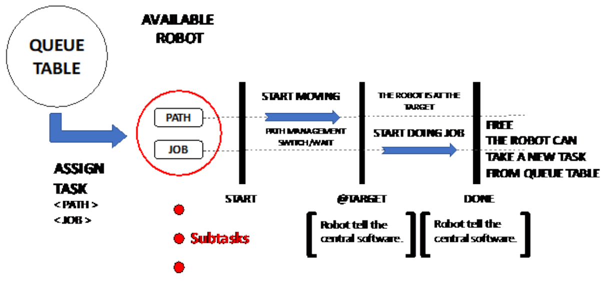


Fig. 3 To assign the available AGV to the queue and update the table queue.

The subtasks that the AGV can do are a cart's heading adjustment, an AGV's heading adjustment, cart hooking, and cart releasing in Fig. 4. The subtask concept is also flexible for various applications in other industries.

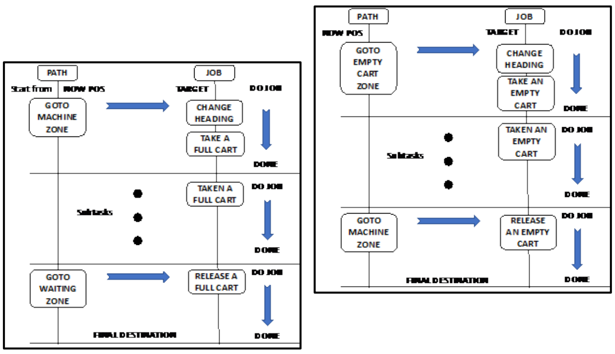


Fig. 4 (Left) Task of taking the full cart to the waiting zone (Zone 3). (Right) Task of taking the empty cart to the machine zone (Zone 2).

4. Path Management

The grids are marked on the layout for significant tasks that the AGV can move past or stop to do a task. The grid positions are not symmetrical or balanced in rows and columns in this plant layout. The central software manages the whole system operation and traffic for the AGVs.

4.1. *Grids Connection to Guided Line*

The guided lines are designed to cover the work area in the plant layout that the grids can be connected to, creating a path for AGVs. The AGV has tasks assigned differently, but it has the same design and capability. The guided line uses magnetic track that has to be constructed under the plant's floor because of durability and long-term operation. The AGV uses the magnetic sensor for line detecting and tracking. The grids of the main lines are mapped to the plant layout, as seen in Table 1. The grid can be detected by the cross junction of magnetic track and RFID.

Table 1. Main line for AGVs

Line	Grid sets of main lines
L0	{0,1,2,3,4,5,6,7,8}
L1	{9,10,11,12,13,14,15,16,17,18}
L2	{9,10,11,19,20,21,22,23,24,25,26,16,17,18}
L3	{6,15,25,48,51,54,57,60,63,66,70,73,75,77,79}
L4	{6,15,16,26,49,52,55,58,61,64,67,71,73,75,77,79}
L5	{7,17,16,26,49,50,53,56,59,62,65,68,69,72,74,76,78,80}
L6	{4,13,22,81,84,87,90,93,96,99,102,105,108,111,114}
L7	{4,13,22,81,82,85,88,91,94,97,100,103,106,109,112,115}
L8	{4,13,22,81,82,83,86,89,92,95,98,101,104,107,110,113,116}

4.2. *Path Switching*

The AGV travels along the defined main lines. If the line is not available or is occupied by others, the AGV has to pause or switch being in the current mainline to prevent collision damage, as shown in Table 2. When the system has many AGVs, the central software has all of the information to analyze and assign a proper path for each AGV.

Table 2. Switching lines across the main lines

Zone	Grid sets of switching lines
1	{{48,49,50},{51,52,53},{54,55,56},{57,58,59}, {60,61,62},{63,64,65},{66,67,68,69},{70,71,72}, {73,74},{75,76},{77,78},{79,80}}
2	{{0,9},{1,10},{2,11,19,20},{3,12,21,22},{4,13,23}, {5,14,24},{6,15,25},{16,26},{7,17},{8,18}}
3	{{81,82,83},{84,85,86},{87,88,89},{90,91,92}, {93,94,95},{96,97,98},{99,100,101},{102,103,104}, {105,106,107},{108,109,110},{111,112,113}, {114,115,116}}

The path-switching method helps to manage the traffic of the multiple AGVs' operation under the limited guided lines. It is similar to railroad switching, but Fig. 5 indicates that it has many possibilities for switching the main lines via the cross lines.

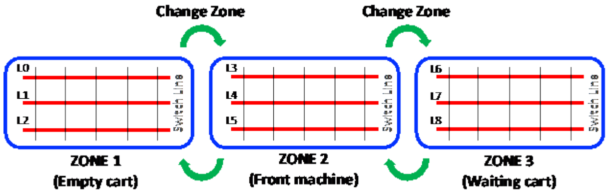


Fig. 5 Main lines in zone 1, zone 2, and zone 3, including switching lines in each zone.

4.3. *Traffic Manager*

In Fig. 6, the central software has perceived the intersection points of the AVGs' paths. It monitors the critical distances by extending each AGV's path. However, it takes time to do the job at a target. The central software also has to calculate the time that corresponds to doing a job and traveling. Besides the collision problem, bottleneck conditions can occur when AGVs have to wait for too long for the current path to clear. This might result in a traffic problem that is inefficient for productivity, even if the AGVs can get to the destination.

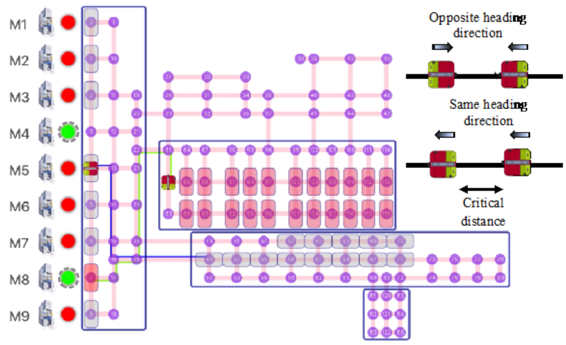


Fig. 6 Collision monitoring using all paths of AGVs in the central software

5. Results

The experiment took one hour and 32.54 minutes (from 3:24:34 p.m. to 4:57:28 p.m.) to complete 24 instances of transportation by cart. There are work areas 7 m^2, 57 m^2, and 72 m^2 for zone 1, zone 2, and zone 3, respectively. The priority task started from zone 2 to zone 3 in order from grid 116 to 82. The pattern to transfer the empty carts from zone 1 to zone 2 had six grids, from grid 48 to 55, which ran in a loop repeatedly, as in Fig. 7. The buttons were independently pressed by the workers and then appended to the queue, as in Fig. 8.

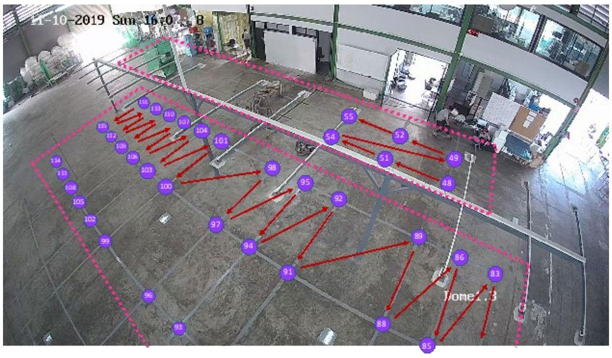
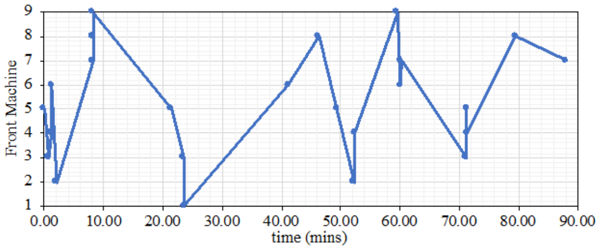


Fig. 7 The travel pattern via grids in the plant layout for carts' transportation

It took every 3.40 minutes to press the button once of totally one hour and 28.15 minutes (or 88.15 minutes).



Fig, 8 The nine buttons in front of the machine are pressed independently 24 times

There were two AGVs separately operating in the experiment. One AGV had the full-cart-out task, and another AGV had the empty-cart-in task. It took 3.52 minutes, on average, for one cart to finish taking out the full cart and taking in the empty cart to the front machine. The AGVs had the same design, traveled by the same speed (0.5 meters per second), and had the same setting and behaviors. They worked overlap in zone 2, which made it possible for the AGVs to crash and bottleneck. As long as there is a task in the queue, the AGVs do not stop working but continue running to the next queue. The completion time of the full-cart-out task and the empty-cart-in task were approximately in the linear. Meanwhile, the time to pause and do a job were the interferences, as in Fig. 9. The workers take time to load the foam product to the cart, about 30–60 minutes, depending on the size of the foam product. The workers then call the AGV to take the full cart out and replace it with the new empty cart. Fig. 10 shows the time that the worker at the front machine has to wait for the AGV to start taking the full cart out. The problem that can occur is when the workers call the AGV at the same time. Then the AGV has to complete the tasks in the queue one by one. The tasks that are not assigned to the AGVs have to wait up to 20 minutes, which is a very long time.

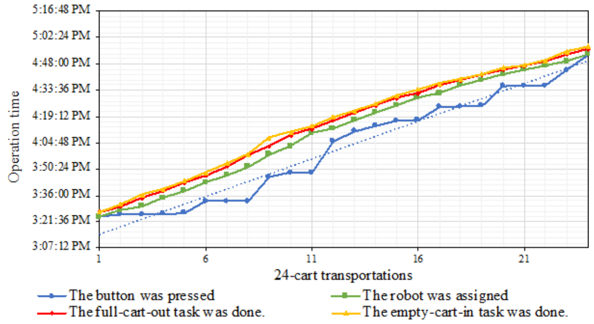


Fig. 9 All complete tasks to place 24 full carts in zone 3 and 24 empty carts in zone 2.

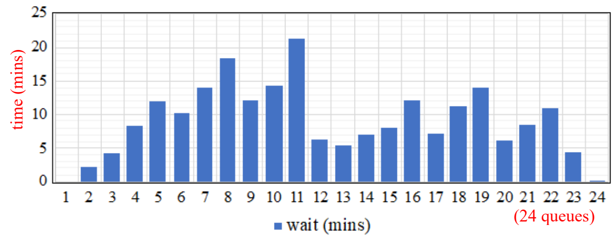


Fig. 10 The AGV waited to start working and take the full cart out until after the worker pressed a button on the front of the machine 24 times.

6. Occupancy Grid Map

The occupancy grid map of the plant layout has merged the information of RFID grids in the red dots in Fig. 11. The map floor plan has two purposes: The first is for the automated task and path management simulation. The second is for path-planning navigation strategies without a magnetic track–guided line. The AGVs can update their current positions on the occupancy grid map using SLAM and fuse the information from magnetic tracking and the RFID grid to the correct position. Therefore, the AGVs can move freely outside the magnetic track and return to the track again. When an AGV moves on the magnetic track, it can park quickly and precisely and save space to accommodate as many carts as possible. There are many optimizing solutions that can be tested in scenario software simulation using an occupancy grid map. For safety purposes, the AGVs can recognize the hazmat labels in the factory [4]. Other labels can be used as visual commands for the AGVs.

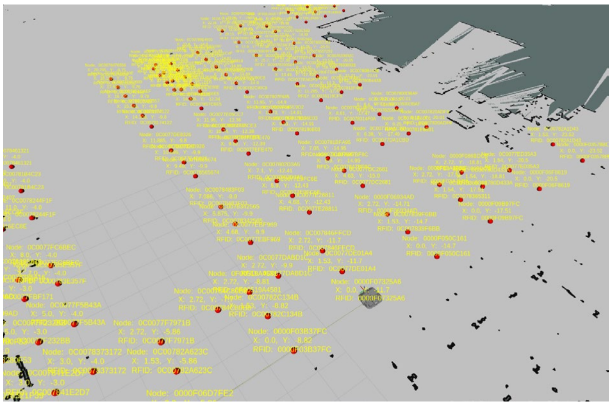


Fig. 11 The occupancy grid map of the factory plant layout built using Lidar SLAM for scenario simulation

7. Conclusion

On average, the transportation of one cart takes 3.52 minutes to finally replace a new empty cart and ready for a worker to load the foam product to the cart. However, the system needs to add more AGVs to decrease the waiting time in the queue. To increase work efficiency, the speed of the AGVs should be adjustable when they do not hook the cart; this can speed up as well as slow down the subtasks. Furthermore, the simulation software development can save costs by finding the best solution without necessitating tests at the factory.

Acknowledgements

This work is supported by the Thai Research Fund (TRF) and Polyfoam Manufacturing Co., LTD under the contract no. RDG6050047.

References

1. Pérez-Rubio, M.C., Losada-Gutiérrez, C., Espinosa, F., Macias-Guarasa, J., Tiemann, J., Eckermann, F., Wietfeld, C., Katkov, M., Huba, S., Ureña, J. and Villadangos, J.M., A realistic evaluation of indoor robot position tracking systems: The IPIN 2016 competition experience. Measurement, 135, 2019, pp. 151-162.
2. Amornphun Phunopas, Wisanu Jitviriya, Noppadol Pudchuen, Sutee Kumjaikong, Songklod Tunsiri and, Eiji Hayashi. Automated Guided Vehicle System Analysis in Foam Manufacturing Plant Using Petri-net. Proceedings of International Conference on Artificial Life and Robotics. 24. 2019, pp. 622-625.
3. Phunopas, A., Blattler, A. and Pudchuen, N., iRAP Robot: World RoboCup Rescue Championship 2016 and Best in Class Mobility Award. In Robot World Cup, Springer, Cham. 2016, June. pp. 554-564.
4. Jitviriya, W., Chaicherdkiat, P., Pudchuen, N. and Hayashi, E., Development of Automation Recognition of Hazmat Marking Chart for Rescue Robot. Journal of Robotics, Networking and Artificial Life, 5(4), 2019. pp.223-227.

==

Authors Introduction

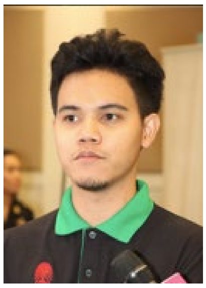
Dr. Amornphun Phunopas

He is an Assistant Professor of Faculty of Engineering at King Mongkut's University of Technology North Bangkok in Thailand. He graduated from Institute of Field Robotics (FIBO) in 2009. He received his D. Eng. degree in Mechanical Information System from Kyushu Institute of Technology in 2012.

Dr. Wisanu Jitviriya

He is an Assistant Professor of Faculty of Engineering at King Mongkut's University of Technology North Bangkok in Thailand. He graduated from the Department of Electrical Engineering, King Mongkut's University of Technology North Bangkok, in 2011. He received his D. Eng. degree in Mechanical Information System from Kyushu Institute of Technology in 2016.

Mr. Noppadol Pudchuen



He received his B.E. degree from Department of Mechanical Engineering (honors) in 2015 and received his M.Eng. from Department of Instrumentation and Electronics Engineering in 2017, King Mongkut's University of Technology North Bangkok in Thailand.

Mr. Songklod Tunsiri

He received his B.Eng. degree from Department of Mechanical Engineering Technology in 2011 and received his M.Eng. from Department of Instrumentation and Electronics Engineering in 2015, King Mongkut's University of Technology North Bangkok in Thailand.

Dr. Eiji Hayashi

He received his PhD from Graduate School, Division of Science and Engineering, Waseda University, Japan in 1994. He is a Professor in Faculty of Computer Science and Systems Engineering, Kyushu Institute of Technology, Japan. His main research interests are Perception information processing and Intelligent robotics system

==