DESIGN AND OPTIMIZATION OF AN AUTOMATED MODULAR SYSTEM FOR DISTRIBUTION, MOVEMENT AND STORAGE OF GOODS

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Annotation

The automation of various processes, the development of technological potential and the ongoing fourth industrial revolution lead companies to digitize and automate business processes. In order to adapt to the fourth industrial revolution, Šiauliai State College representatives, together with the engineering staff of the companies, have taken the initiative in this area. During the implementation of INOSTART projects, automation processes were design, adapted for warehouses and helping workers to transport heavy loads. A logistics system has been created, which integrates a mobile logistics robot using image detection cameras and distance measuring laser systems, as well as optimized system performance.

Keywords: automation, logistic terminal, prototyping, robots, optimization.

Introduction

With the rapid development of technology and innovation, more and more is invested to a digital technology and automated solutions. To increase the efficiency of technological processes, industrial robots are used to perform repetitive and monotonous tasks. These automated devices allow companies to speed up production and logistics processes, use resources more efficiently, increase work speed, productivity and business competitiveness. Increasingly, workers are working hand in hand with robots or robotic production systems. Humans play major role in the design process, development, maintenance, installation and the whole management process. The well-defined allocation between technology and an operator is a contribution alliance for a competitive manufacturing system. The process of automation is expressed in some different cases as the necessity, which will increase the human safety in the production process (Mishev, 2006). Conventional industrial robots are not adapted to work with humans, so for safety reasons they work in designated enclosed areas. Many logistics companies make decisions where robots (collaborative) can work safely in the same environment with humans and collaborate safely. Automated warehouse deployment requires significant investment, so when making decisions, the company must evaluate which process needs to be automated, process capacity, warehouse design, security, and so on (Matta and Semeraro, 2005; Mishev, 2006). It is especially relevant in nowadays of business environment, where companies are looking for ways to quickly and financially sufficiently implement automated technological workforce. Warehouse automation allows achieving high-quality and fast customer service and reduction of operating costs (Mingxing et al., 2018). Some researches show (Barosz et al., 2020; Glaser, 2009) that thanks to robotization, many companies obtained an increase of productivity by 30%. The implementation of automation is usually connected with reduction of the human cost. Many warehouses in Lithuania are still non-automated and that automation is not fast due to high costs.

The purpose of the smart machine is to integrate into the company's warehouse, where it would facilitate human work and reduce the number of errors in the collection of ordered goods. The automation of warehouse processes, which increases the productivity of work in business enterprises, is described in this paper. Dijkstra algorithm for collecting goods on the optimal route was implemented and tested. Solutions that minimize the project costs were chosen during the implementation of this project.

Purpose of experimental tests. To perform experimental tests of the logistics robot orientation system based on the Dijkstra algorithm. Provide recommendations for system optimization.

Methodology for performing experimental tests. The testing of the logistics robots was performed in a real commercial warehouse. The robot moves in the warehouse, orienting according to the lines and barcodes drawn on the floor. The coordinates of the warehouse are coded in the barcodes marked on the floor of the warehouse. Warehouse goods are assigned to a specific warehouse coordinate. After creating a product order according to the list of goods, the route of the robot's movement is created based on the Dijsktra algorithm. The operation of the robot control systems was tested during the experiment.

1. Methodology of order

Creating an order. The warehouse employee selects the ordered goods and their quantities in the Microsoft NAV window. These goods are also assigned to the order box.

Recording of goods. Order execution is assigned to an external device - a terminal. In this case, there may be one or more devices.

When warehouse worker approves, the pick-up instruction is formed and sent to the peripheral device - terminal via wireless connection.

In the business management system is possible to specify the peripheral device number. Depending on the selected peripheral device it is generated a .csv file (TAB delimited) and then it transferred to the directory - "FTP address for export".

If not all goods are in stock, system is showing a question "Do partial selection?", after confirmation the only quantities/goods with sufficient balance are printed, and without confirmation the pick-up instruction is not printed. When creating an order, system is checking possibility to scan goods in packages and creating a line with the quantity in a package, also a line showing a barcode of the package. The remaining quantity is written in the next line with the barcode.

FtpRemoteFileHandling (1.0.16.0) is subroutine for administration of orders in the Programmable logic controller (PLC) FTP server. If the order is not initiated, the import folder is constantly checked, and when the .csv file appears, information about it is transferred to other subroutines.

After receiving the information about the new order, the order is opened using the file opening subroutine (Fig. 1). This subroutine all values in a .csv file convert to variables for PLC.

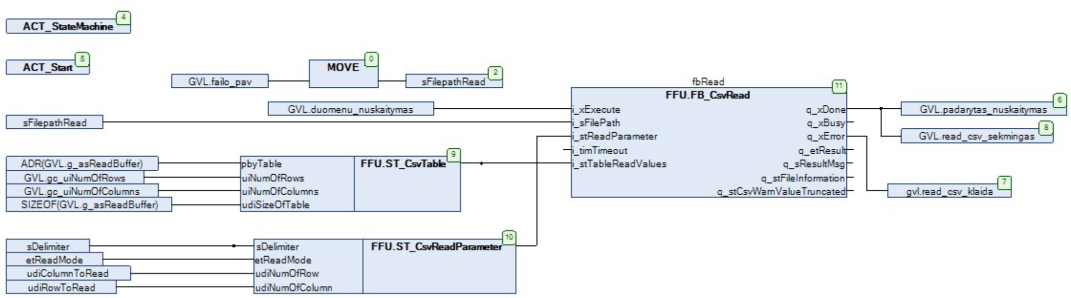


Fig. 1. Scanning a file

A prototype of a mobile logistics robot has been developed for the transportation of goods in the warehouse. Robot operation algorithm:

The camera captures the current location of the device.

The Ethernet / IP scanner reads the information about current position.

From the obtained data is calculated average value which indicates the current location.

The obtained value is transferred to the motor control program (Fig. 2).

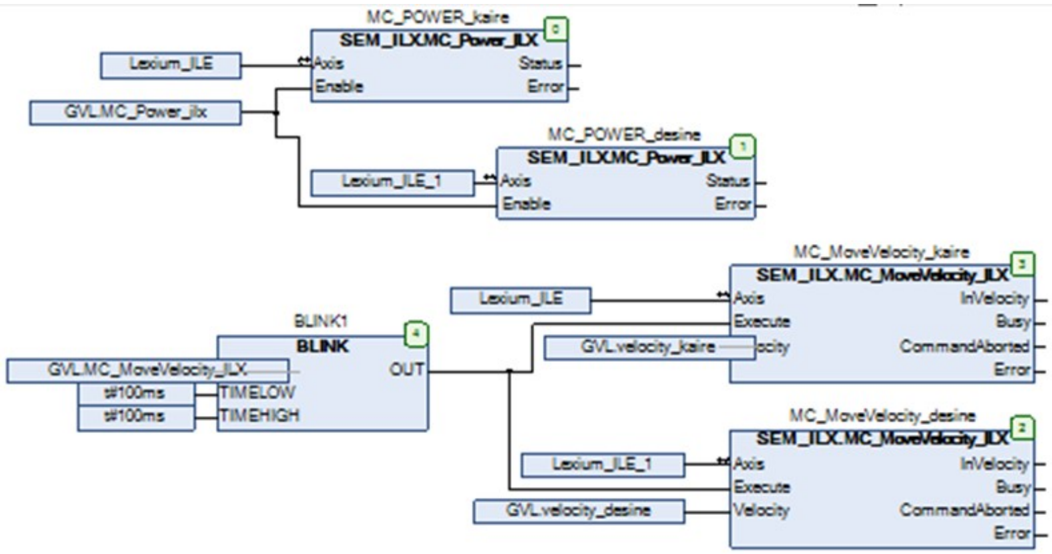


Fig. 2. Engine management program

The information about required order is displayed on the touch screen. When required item is scanned robot moves to another position.

The information from the barcode scanner is transmitted to the PLC.

When the scan is completed, the order is deleted from the import folder.

The order report with the selected quantities of goods is generated and saved in .csv format in the export folder.

The report is run through the job queue, and runs automatically. The quantities of goods are picked up and entered in the "Quantity for dispatch" field. Quantities received during export are recorded and registered in the "Transfer log" file.

2. Path planning method

Path planning techniques are an important aspect of a robot navigation system. The robot must reach the aim in the shortest time by the optimal route. Another important aspect is the computational complexity and resources of the method. Path planning methods can be categorised into global planner and local planner. Global planner is used in static environments as Dijkstra's algorithm or A* algorithm. Local planner is used in a dynamic environment as Neural Network for predictive trajectory, when a sensor system is used to detect and avoid obstacles. Various approaches and its comparisons can be found in the literature Zafar and Mohanta (2018), Patle et al. (2019), Koubaa et al. (2018) and so on.

Commonly used path planning methods for example are A* algorithm or Dijkstra's algorith. Heuristic A* algorithm is similar to dynamic and is widely used in programming, artificial intelligence and robotics. The Dijkstra algorithm for optimal routing can be applied to the navigation system, which is used to find the shortest path between the node and every other (Lu and Camitz, 2011). The algorithm exists in many variants; Dijkstra's original variant found the shortest path between two nodes, but a more common variant fixes a single node as the "source" node and finds shortest paths from the source to all other nodes in the graph, producing a shortest path tree. The single source shortest path problem can be described as follows (Maw and WaiPhyoEi, 2017):

$$\text{new } d_j = \min\{d_j, d_i + c_{ij}\},$$

where

d_i = distance of current node;

d_j = distance of label node;

c_{ij} = weight set for the edges(i,j).

Algorithm step by step updates the states of the nodes (Fig. 3).

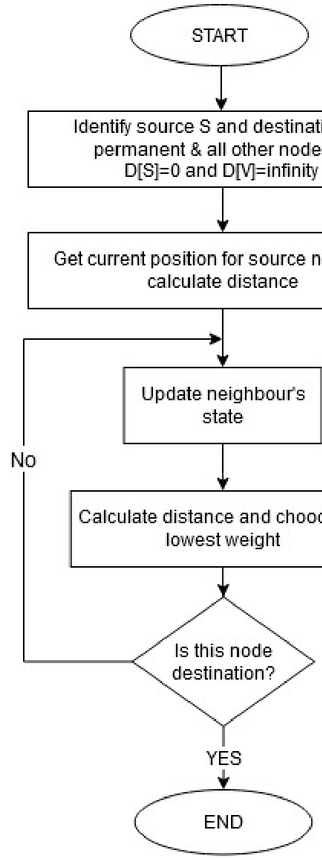
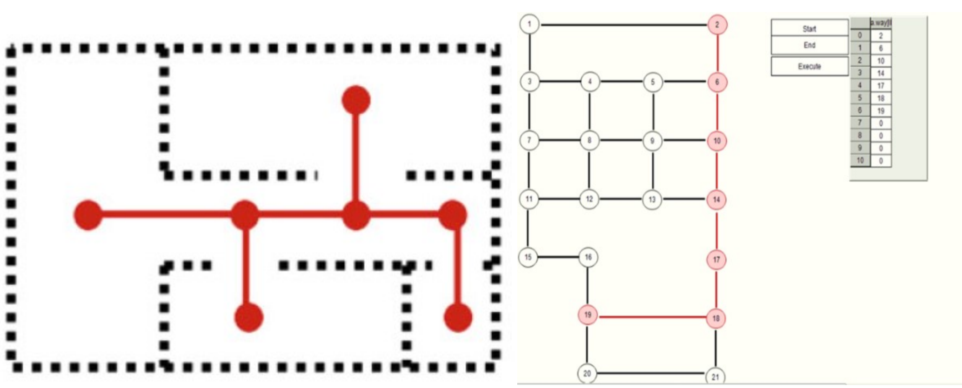


Fig. 3. Flow chart of the shortest path calculation

Dijkstra algorithm was realized by CODESYS system in the project. Fig. 4 shows the shortest path tracking of movement in the warehouse.



(a) (b)

Fig. 4. (a) Qualitative Path Planning (Koubaa et al., 2018); (b) Realization of Dijksta algorithm

This algorithm specify by routes from the initial to target location. The robot moves from start node to desired node along the shortest path. Landmarks are any kind of recognizable and perceivable objects that can uniquely identify a location. Architecture of robot orientation in the environment: line-barcode-ultrasonic sensors.

3. Realization of the project

Standard universal tools and instruments were adapted for the project implementation: a standard business management system has been chosen for warehouse management (Navision) and universal controllers instead of specialized ones for robot control.

An automated modular system for business and management orders in logistics warehouses has been constructed (Fig. 5).

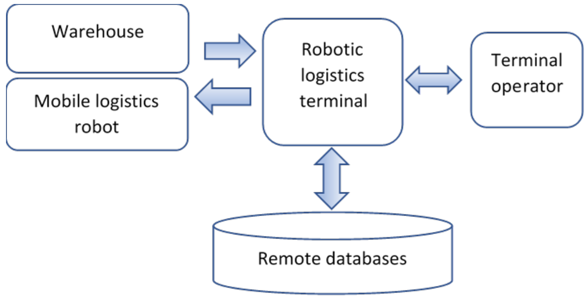


Fig. 5. Control scheme of logistics terminal

The program was written for the controllers based on the Dijkstra algorithm and developed middleware modules for receiving and transmitting commands between controllers and the Business Management System (can be of any type). The project was installed and tested in a typical warehouse of the trading company (with racks and shelves) without large investments.

Conclusions

Tests and trials of the developed automated system were performed in the warehouse of a company, fixed system errors, devices compatible with the business management system. In most cases, warehouses have business management systems in place, so all that remains is to implement additional intermediate models. This reduced project costs by using standard rather than specialized hardware and software. The Dijkstra algorithm has been implemented to collect goods by the most optimal route.

It is also suggested to adjust the gear control systems as they do not work stably at all speed modes. Adjust the operation of electric motor encoders. Perform improvements to the robot's optical systems to increase scanning accuracy and speed.

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