AGV Guidance System Simulation with Lego Mindstorm NXT and RobotC

Violeta Kostova[1], Ramona Markoska[2] and Mitko Kostov[3]

Abstract **– The paper gives an analisys of automated guided vehicles navigation systems. A simulation of guidance is presented by using LEGO Mindstorm NXT package. On the basis of theoretical studies and experience, a robot is programmed in the programming language RobotC in order to demonstrate the functionlity of real AGV vecihle-forklift.**

Keywords **– automated guided vehicles, navigation, LEGO NXT, robotics, RobotC.**

I. Introduction

Productivity and flexibility are the primary goal of today's automation technology, what can be achieved only in a fully integrated production environment. The high demands in the production often cause chaotic situations in warehouses. Human mistakes negatively affect the safety in a production environment, efficiency and quality of products. These disadvantages are reduced by introduction of automated guided vehicles (AGV).

Automated guided vehicles are among the fastest growing classes of equipment in the material handling industry. They are battery-powered, unmanned vehicles with programming capabilities for path selection and positioning. They are capable of responding to frequently changing transport schemes, and they can be integrated into fully automated intelligent control systems. The aim is to improve efficiency in material transfer and increase production, which results AGV to be used in production lines of modern manufacturing plants.

Integrated intelligent computers allow automated guided vecihles to safely operate at higher speeds while transferring the products. Precise movements and rotation allows management in narrow space. They can significantly reduce the need for human recourses to carry goods in a manufacturing plant. An unmanned AGV vehicle uses optical path for fast and safe movement in warehouses. It is remotely driven vehicle that can perform operations like picking up load, transferring it through a set of predefined paths and its delivery to the specified locations.

Introduction of unmanned vecihles in the warehouses has a big effect on safety. With help of sensors, automated guided vehicles can detect objects in its path. Automation eliminates or solves the problem of traffic congestion and reduces the possibility of accidents.

This paper presents the results of simulation of navigation and operating of automated guided vehicles. A robot is designed to demonstrate the functionality of the AGV vehicle. Based on theoretical studies and experiences, the robot is programmed to demonstrate the functionality of real-forklift AGV vehicle.

The paper is organized as follows. After the introduction section and the explanation of the need of these vehicles to improve safety in the production environment, efficiency and quality of production, the second section reviewes the types of AGV vehicles navigation and guidance. The third section describes the hardware and software platform that are used in simulations presented in the fourth section. The fifth section concludes the paper.

II. Vehicle Navigation

Navigation and guidance systems of AGV vehicles evolved a lot from the moment they emerged up to date. There are two basic principles for AGV navigation – following a fixed path/route and free navigation. AGV navigation with fixed route is the oldest type of navigation. It is used today, but most of AGV systems are with free navigation, which allows flexibility and easier maintenance. Some of the most important technologies of navigation based on these two principles include: (i) Wired guide: wires are embedded in the floor and they are detected to determine the vehicle's position relative to the wire. (ii) Inertial guide: gyroscopes and wheel odometers are used (for measuring the traveled distance) in order to conduct very precise guidance. Magnets placed in the floor at regular intervals are used to reset. (iii) Laser guide: a rotating laser transmitter-receiver is installed in the vehicle. The navigation is based on the emitted and reflected laser beams. The angle and distance of movement of the vehicle are calculated and compared to parameters in preset network. As a result, the AGV vehicle can find its location.

A. Fixed path (wire guidance)

This type of guidance was the main way in development of AGV industry in 1970's. AGV vehicles that follow a fixed path have a fixed route sensor on the underside of the vecihle, which detects the path in the ground surface. The sensor role is to detect a path, and to guide the vehicle just over the path. If the path is turning, the sensor detects the absence of path, returns a feedback to the vecihle control, which guides the vecihle to the right path. The role of the sensor in conjunction with the control and steering system is to keep the AGV vehicle on the path.

[1]Violeta Kostova is with the Faculty of Technical Sciences, Ivo Lola Ribar bb, 7000 Bitola, Macedonia, E-mail: kost.violeta@gmail.com.

[2]Ramona Markoska is with the Faculty of Technical Sciences, Ivo Lola Ribar bb, 7000 Bitola, Macedonia, E-mail: ramona.markoska@uklo.edu.mk.

[2]Mitko Kostov is with the Faculty of Technical Sciences, Ivo Lola Ribar bb, 7000 Bitola, Macedonia, E-mail: mitko.kostov@uklo.edu.mk.

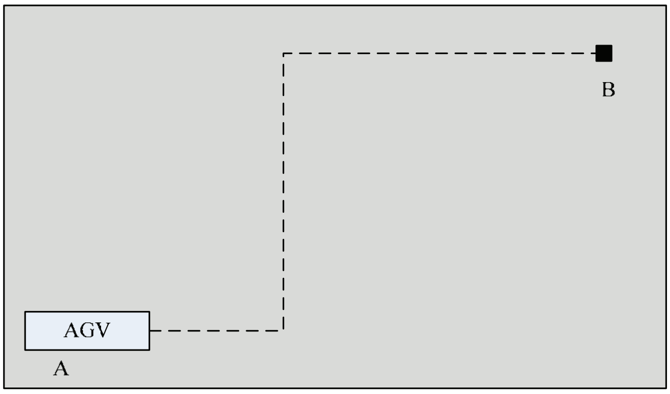

Fig. 1. Fixed path of an AGV vecihle.

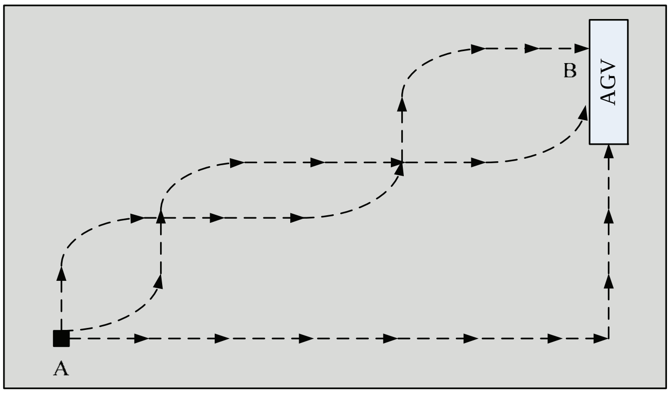

Fig. 2. Free paths of an AGV vecihles.

The main characteristics of an AGV system with fixed path (Fig. 1) are: the paths of the AGV are well marked on the floor, continuous and fixed, but they still can be changed. Different types of marking the paths are used, but systems with inductive guidance and systems with optical guidance can be distinguished.

This is a simple method of navigation that requires a very simple resources. But the main drawback is that AGV vehicle can only follow the line, and thus its operations are very limited. In addition, the vehicle does not know its current position in the track. Further issue of strategies based on following route is cost and time required to set tracks. In some cases there is a need several AGV paths to intersect with each other, which can confuse the sensor for following the path. These strategies are also non-flexible in a case of need for new investment and it takes time to modify the path of the vehicle. The vecihles are also highly dependent on the track - if they lost contact with the track, they can no longer operate. This condition may occur due to corrupt or obscure track, but can also occur in case AGV vehicle too quickly accessing a turning point.

B. Free navigation (non-wire guidance)

In the 1980's non-wire guidance is introduced. It does not suffer from the above problems and it is based on localization of AGV vehicle. Localization differs from following a line because it tries to specify the position and orientation of the vehicle in relation to the environment rather than making small adjustments in its movement. AGV vehicle is not limited to movement along a fixed path, but rather any position in the environment is permitted (Fig. 2).

The laser and inertial navigation are examples of this kind of navigation. They provide increased accuracy and flexibility of the system. When it is necessary to make adjustments to the path, there is no need to change the infrastructure, thus there is no slowdown in production and transport process.

For navigating in unrestricted open space, wireless AGV systems at any moment have to know vehicles' position and always to be able to determine the path to the end point, without the benefits of systems with fixed paths.

AGV systems with free navigation have a map of the area in which the AGV functions, which is placed in the memory of microcomputers in the vehicle, as well as more fixed reference points in the working area of the AGV, which can always be detected by the vehicle.

The vehicles also have planned routes. During the movement of the vehicle, the microcomputer measures the traveled distance, direction and angle of turning of the vehicle.

Decoders placed on the wheels provide data for the traveled path and the change of direction. This technology allows independent movement of the vehicle, but due to errors in measuring the actual position of the vehicle differs from the calculated position. Correction of the position of the vehicle is done by external reference points.

III. DESCRIPTION OF THE HARDWARE AND SOFTWARE SIMULATION PLATFORM

Lego Mindstorm NXT 2.0 package contains hardware and software which can be used to construct small programmable robots that can be easily adapted to different needs. The package includes a programmable 32-bit ARM7 microcontroller that can be programmed to perform various operations, 256KB Flash and 64 KB RAM memory, a set of sensors, motors and Lego-blocks for constructing mechanical systems.

Designed robots can be programmed in different programming platforms: LabView, Matlab, Robolab, C, C++, Visual Basic, Java, RobotC, etc.

From a communication point of view, the controller has a USB port for loading a program from computer. For this purpose bluetooth connection can be used. In addition, the controller has four inputs and three output ports. The four input ports can be used for attaching different sensors: color sensor, touch sensor, light sensor, ultrasonic sensor (to detect objects at a distance), sound sensor, etc. The three output ports are used for attaching of three servo motors, labeled A, B and C. Bluetooth wireless communication allows robot to communicate and cooperate with other NXT microcontrollers, receive orders from computers, smart phones and other bluetooth devices.

IV. DESCRIPTION MODEL

For the simulation purposes, AGV-forklift vehicle that uses wire guidance is constructed (Fig. 3). Lego Mindstorm NXT

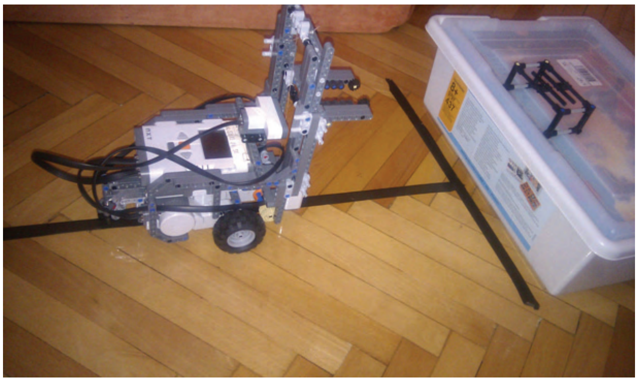

Fig. 3. The vecihle that was used for the simulation.

Fig. 4. The polygon for operating of the AGV vecihle.

2.0 package is used, since it allows easily and fast to construct robots and mechanical systems, which can then be programmed to perform different operations.

The vehicle communicates (takes orders) with a communication center and according to the received commands it transports load from one workstation (A, B, C and D) to another. The stations in the polygon are connected by tracks, as it is illustrated in Fig. 4. The communication with the communication center is simulated by using bluetooth connection with a smart mobile phone that runs the operating system Android. The idea is by sending different data through the phone, to give a certain command to the vehicle to perform some operation.

The block diagram of the algorithm for vehicle operating is given in Fig. 5. At the beginning, the vehicle is in listening mode. When the vehicle receives data through bluetooth, it checks if data is 0, 1 or 2, and afterwards it stops (for received data 0) or performs sequences belonging to the respective scenario (Scenario 1 or Scenario 2 for received data 1 or 2, respectively). According to Scenario 1, the vehicle (from the workstation A) is sent to the station B, where it takes load and transfer the load to station C by following a path. According to Scenario 2, the vehicle is sent to the station C (by following a path), there it takes load and transfer the load to the station D.

The functionality of the vehicle in terms of navigation and interaction with the environment is made possible by incorporating several different types of sensors. The light sensor is located on the bottom of the vehicle and used for detection of the different intensity of the color of the line compared to the surface, which allows the vehicle to be able to follow this line. Ultrasonichniot sensor is located in the front of the vehicle in order to detect objects ahead.

For the simulation of the vehicle activities, a program code is written in the programming language RobotC.

The block diagrams of Scenarios 1 and 2 are illustrated in Fig. 6, while the source code of the simulation program written in RobotC is completely given in [11]. According to the program, the vehicle listens to a command and if there is command 1 or 2, it moves and follows the navigation track by using the light sensor, while in the same time the ultrasonichniot sensor checks if the vehicle reached the target, i.e. it move until the criterion for detection the station is satisfied to load or unload. Once the station is detected, depending on the scenario, the vehicle loads or unloads the load.

By applying the made model and the software solution, a number of simulations are performed. It is concluded that this platform, besides simplicity and low cost, is quite enough for studying and simulating all aspects of a modern production and the need of automatic guided vehicles. The communication capabilities of the NXT controller and the ability to connect and exchange information with other vehicles give possibility in future studies to analyze the concepts of cooperative action of a group of vehicles to perform the same task by using different evolutionary algorithms and other modern concepts which are being studied today in intelligent systems.

V. Conclusion

The possibilities of AGV vehicles are enhanced with the ability to send and receive data through data communication. This flexibility of AGV vehicles, as a result of remote communication, allows them to interact with other autonomous vehicles and be capable of various operations. A continuous coordination between vehicles contributes to efficiency and savings in finance.

The paper analyzes the automatic guided vehicles navigation. A robot is designed in order to demonstrate the functionality of a typical model of AGV vehicle - forklift. On the basis of theoretical studies and experiences, the AGV robot is programmed to demonstrate the functionality of the operation of real AGV vehicle. A software solution is developed according to which the vehicle performs a specific task and it is concluded that this platform can be successfully used for simulation of processes involving automatic guided vehicles.

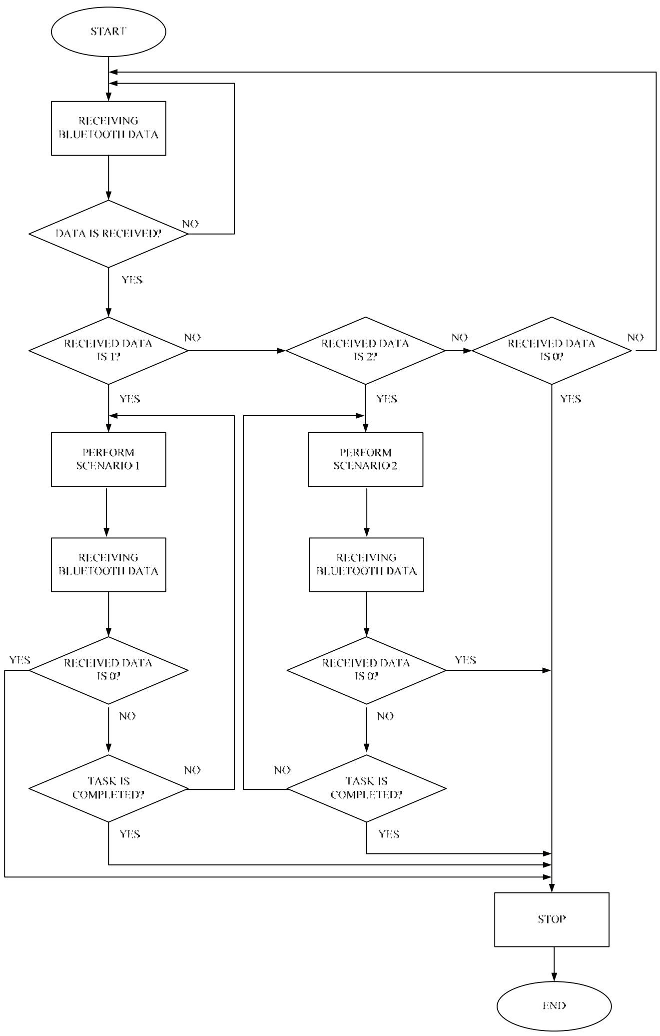

Fig. 5. Bloch-diagram of the software solution.

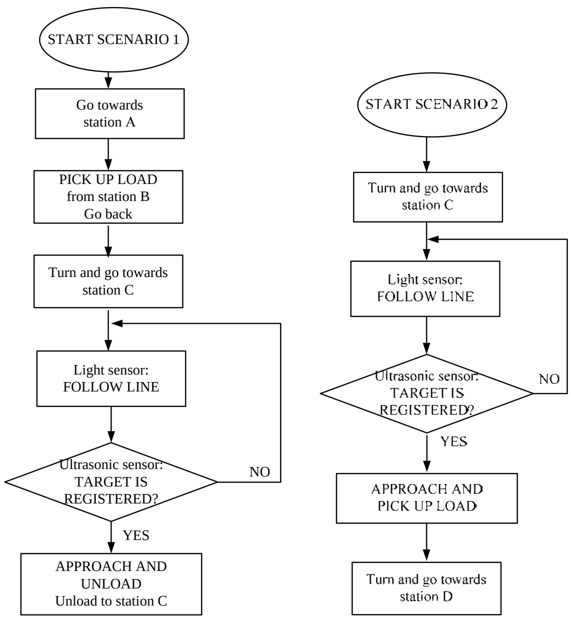

Fig. 6. The two scenarios of operating of the AGV vehicle.

REFERENCES

[1] T. Tsumura “Survey of autonomous guided vehicles in japanese factory”, Proceedings of the IEEE International Conference on Robotics and Automation, pages 1329-1334, San Fransisco, CA, April 1986.

[2] I. J. Cox and G.T. Wilfong, editors, “Autonomous Robot Vehicles”, Springer-Verlag, USA, 1990.

[3] H. K. Shivanand, M. M. Benal, V. Koti, Flexible Manufacturing System, New Age International Limited, Publishers, 2006.

[4] S. Butdee, A. Suebsomran, F. Vignat, P.K.D.V. Yarlagadda, “Control and path prediction of an Automate Guided Vehicle”, Journal of Achievements in Materials and Manufacturing Engineering, Dec. 2008.

[5] Atul Tiwari, “Scheduling of Automated Guided Vehicles in Flexible Manufacturing Systems environment”, 2010.

[6] Rajeev K Piyare, Member, IAENG, and Ravinesh Singh, “Wireless Control of an Automated Guided Vehicle”, Proc. of Int. Conf. of Engineers and Computer Sc., Hong Kong, 2011.

[7] Axel Hoff, Holger Vogelsang, Uwe Brinkschulte, Oliver Hammerschmidt, “Simulation and Visualiation of Automated Guided Vehicle Systems in a Real Production Environment”.

[8] Ryan G. Rosandich, Richard R. Lindeke, Jeff Berg, “Developing an Automatic Guided Vehicle for Small to Medium Sized Enterprises”.

[9] Axel Hoff, Holger Vogelsang, Uwe Brinkschulte, Oliver Hammerschmidt, “Simulation and visualization of Automated Guided Vehicle Systems in a Real Production Environment”.

[10] Dinis Fernandes, Luís Farrolas, Pedro Brito, Pedro Lima, “Progresses on the Design of Small Flexible Automated Guided Vehicles”.

[11] Violeta Kostova, " Industrial application of automated guided vehicles" (MSc thesis), Faculty of Technical Sciences Bitola, 2012.

[12] Markoska, R., “RobotC programming“, (teaching materials). International project for Development of Regional Interdisciplinary Mechatronics Studies, TEMPUS DRIMS, 2012.