AGV guidance system simulations with a programmable robotics kit

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Abstract: This paper gives an analysis of automated guided vehicles navigation systems. Two types of guidance are analysed and simulated by using Lego Mindstorm NXT package – fixed-path guidance through line following as the oldest type and vision-based guidance as a low-cost guidance system that utilises mobile phone camera for tracking marks and detecting obstacles. On the basis of theoretical studies and experience, robot can be programmed in the programming language RobotC in order to demonstrate the functionality of real AGV vehicles.

Keywords: automated guided vehicles; AGVs; navigation; vision; Lego NXT; robotics; RobotC.

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1 Introduction

Productivity and flexibility are the primary goal of today's automation technology, what can be achieved only in a fully integrated production environment (Butdee et al., 2008; Shivanand et al., 2006; Tiwari, 2010). 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 (AGVs).

AGVs are among the fastest growing classes of equipment in the material handling industry (Cox and Wilfong, 1990). 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 vehicles to be used in production lines of modern manufacturing plants (Piyare and Singh, 2011).

Integrated intelligent computers allow AGVs 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.

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

The intelligence and adaptability of the AGV vehicles is increased by using machine vision, as a cheap and non-invasive way to perceive the environment. Accordingly, vision is becoming more common in navigation approaches in AGV vehicles.

This paper reviews the types of navigation and presents the results of simulation of operating of AGV. Robot can be designed and programmed to demonstrate the functionality of the AGV vehicles. By using Lego Mindstorm NXT package, AGV-forklift vehicle that follows a line is constructed in order to simulate wire guidance. During its fixed route and programmed tasks, the vehicle is capable to detect obstacles by its sensors. In addition, the same NXT package can be used to simulate vision-based AGV vehicle that combines few sensors and is capable of detecting and recognising marks and obstacles. The obtained visual information from the attached mobile camera will be processed and interpreted by the vehicle software and accordingly, corresponding activity will be performed.

This paper is organised 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, Section 2 reviews the types of AGV vehicles navigation and guidance. Section 3 describes the hardware and software platform that are used in simulations presented in Section 4. Section 5 concludes this paper.

2 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 (Rosandich et al., 2002; Sabikan et al., 2010). 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:

1. Wired guide: wires are embedded in the floor and they are detected to determine the vehicle's position relative to the wire.
2. Inertial guide: gyroscopes and wheel odometers are used (for measuring the travelled distance) in order to conduct very precise guidance. Magnets placed in the floor at regular intervals are used to reset.
3. 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 pre-set network. As a result, the AGV vehicle can find its location.
4. Vision-based guide: the navigation system detects and recognises signs, which are processed by using image processing techniques.

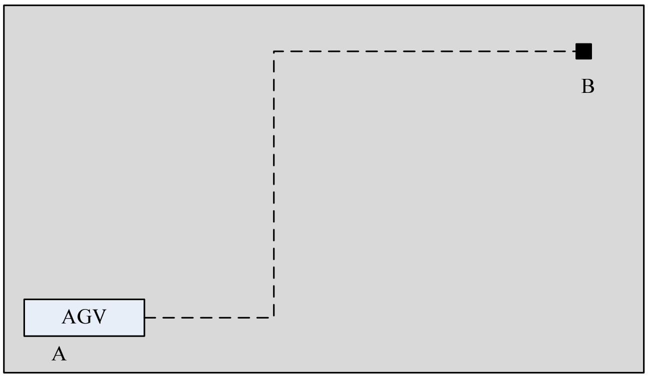
2.1 Fixed path (wire guidance)

This type of guidance was the main way in development of AGV industry in 1970s. AGV vehicles that follow a fixed path have a fixed route sensor on the underside of the vehicle, which detects the path in the ground surface (Fernandes et al., 1996). 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 vehicle control, which guides the vehicle 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.

The main characteristics of an AGV system with fixed path (Figure 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 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 vehicles 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.

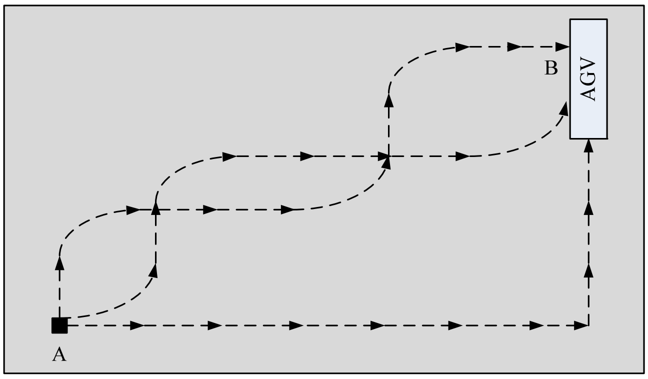
Figure 1 Fixed path of an AGV vehicle



2.2 *Free navigation (non-wire guidance)*

In the 1980s, non-wire guidance is introduced. It does not suffer from the above problems and it is based on localisation of AGV vehicle. Localisation 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 (Figure 2).

Figure 2 Free paths of an AGV vehicle



Vision-based navigation (Chin et al., 2001; Cox and Wilfong, 1990; Hoff et al., 1997; Jian et al., 2006) is a newer type of free navigation, where instead of the magnetic tags or lines, a series of image signs are placed along the route. A vision system is required to recognise navigation signs detected by camera attached to AGV vehicle. The low-cost guidance system includes image processing techniques such as segmentation, smoothing, edge detection, etc. for detecting navigation signs and obstacles that might appear on the route.

Vision-based navigation provides increased accuracy and flexibility of the system. Setting up signs is very inexpensive compared to laying down a wire into floor or setting up a laser guidance system (Tsumura, 1986). Route adaptation and plant reconfiguration are simplified and may become part of a standard maintenance practice. When it is necessary to make adjustments to the path, there is no need to change the infrastructure. By change the order and the types of signs in the series, the route can be planned and adjusted flexibly, thus there is no slowdown in production and transport process. It is already an accepted practice, in reasonably clean environments, to mark visibly the AGVs' routes for increased safety of human workers. Furthermore, pre-existing alphanumeric signs or non-human readable alternatives, such as bar codes could be used for environment labelling. In addition, other advantages of this approach include that vision sensors can acquire visual information with high spatial and time resolution in a non-invasive way and they do not interfere with each other when multiple intelligent vehicles are moving within the same area.

At the same time, this approach has a limitation in the decreased robustness of vision sensors compared to laser sensors and radar sensors in extreme illumination conditions, such as fog, night, sunshine, rain. In addition, during a sunny day, various objects could generate shadows and in this way to change environment colour and textures. Also, the other vehicles and obstacles could hide a part of the road, which could result in discontinuity of lane markings.

3 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, 256 KB 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: colour 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, labelled 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.

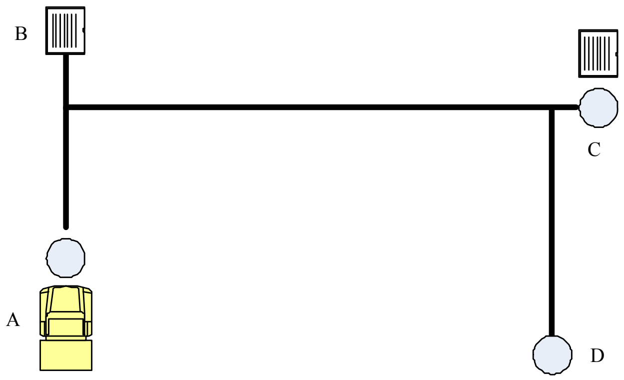
4 Description model

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

Figure 3 The vehicle that was used for the simulation (see online version for colours)

The vehicle communicates (takes orders) with a communication centre 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 Figure 4. The communication with the communication centre 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.

Figure 4 The polygon for operating of the AGV vehicle (see online version for colours)



The block diagram of the algorithm for vehicle operating is given in Figure 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 the path. According to Scenario 2, the vehicle is sent to the station C (by following the path), where it takes load and transfer it to the station D.

Figure 5 Block-diagram of the software solution

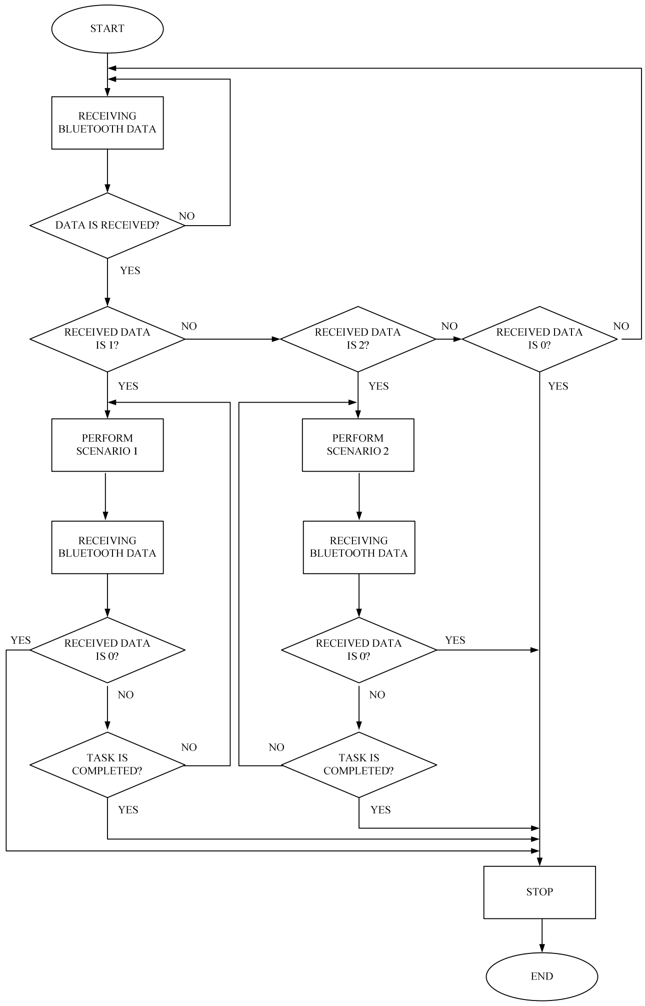
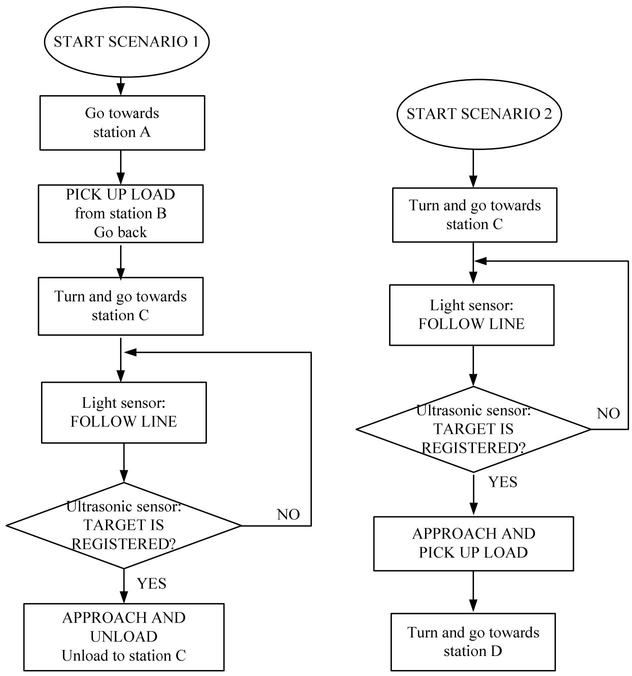


Figure 6 The two scenarios of operating of the AGV vehicle



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 colour of the line compared to the surface, which allows the vehicle to be able to follow this line. Ultrasonic 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 (Markoska, 2012).

The block diagrams of Scenarios 1 and 2 are illustrated in Figure 6, while the source code of the simulation program written in RobotC is completely given in Kostova (2012). 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 ultrasonic 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 analyse 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.

5 Conclusions

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.

This paper analyses 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. According to developed software solution 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.

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