APPLICATION OF MACHINE VISION TO ENSURE SAFETY IN THE VICINITY OF AUTOMATICALLY CONTROLLED VEHICLES IN METALLURGY

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Abstract

The paper deals with the application of automatically controlled vehicles in the metallurgical industry. The aim of the paper is to present a proposal for innovative safety of operating workers in the vicinity of an automatically controlled fire truck during the production of coke. The introductory part of the paper will be devoted to the explanation of the concept of automatically controlled vehicles, their possibilities, areas of their application and specifics in the field of metallurgical operations. The main part of the paper will be devoted to the creation of a proposal to ensure safety in the track area of an automatically controlled fire truck during the production of coke. Security designs using optical barrier fencing and control using PLC Simatic series S7-1200 will be presented. Visualization and control of fencing provided by the visualization program Promotic. The second way of innovative security is the use of a machine vision system using operational cameras on a fire truck. An algorithm based on environment color filtering with subsequent detection of operational workers will be introduced. The algorithm was tested on real camera recordings from the coking plant's operating environment.

Keywords: Automatically controlled vehicles, safety, fire truck, coke plant, machine vision

1. INTRODUCTION

Automated vehicles began to be used in industry in the 1950s. The main goal of these vehicles was to speed up production and logistics, reduce the number of employees and reduce costs through automation. The aim of the article is to design safety in the vicinity of an automatically controlled fire truck during the production of coke. In order for the fire truck to operate in automatic mode, it must comply with safety regulations and a number of conditions that ensure safety for workers moving on the coking plant premises. The first way is to design security by means of security fencing using an optical barrier, which is controlled by a PLC and controlled via visualization software. The second way is machine vision testing, which could be used as a safety supplement.

2. THEORY DESCRIPTION

Automatically controlled vehicles are vehicles that do not require an operator or driver for their function. These vehicles are controlled by a controller (computer). We can find them in households such as: robotic vacuum cleaner, robotic lawnmower and window cleaner. They are most often powered by electricity using batteries. The most common uses of these vehicles in companies are for the transport of materials, cargo and goods. It can be used mainly in warehouses, production halls, distribution centers, but also in department stores. Moving costs is possible directly from the warehouse to the production line. If it is a modern company, everything is possible without the presence of man and thus there is an efficiency of material flow without interruption [1,4,6].

AGVs (Automatic guided vehicles) are designed for moving pallets. In addition to purely automatic forklifts, there are also hybrid types. For these types, it is possible to use both automatic control and purely manual.

Types of automatically steerable vehicles:

- Underride

A rover that has very small dimensions arrives under the container or the object intended for it, connects and then leaves with the container to its destination. The vehicle was to be used for the distribution of material inside hospitals or laboratories.

- Piggyback

Like forklifts, they are used to transport material, especially pallets. Unlike forklifts, however, they cannot load the load on their own.

- Mini-AGV

They are used for easy transport of smaller loads. They can be used mainly in smaller logistics halls, in e-shop warehouses or at post offices.

- AGV assembly and production

They serve primarily for the bulk of different parts between lines, others take the form of mobile robots thatcan also assemble individual parts. These vehicles are very widespread in the automotive industry.

- AGV for transporting people

Most often they can be seen in enclosed spaces, where there is a minimum amount of other non-autonomous means. The use of these AGVs can be found mainly at airports, golf courses, when collecting people from large parking areas, or for visitors to excursions.

Navigation of automated guided vehicles

There are several types of navigation systems. Their use depends primarily on the type of project, the work that the AGV will perform, the environment in which it will move. This is the most important system of these autonomous vehicles.

The main tasks of navigation:

- detection of the direction of movement and speed of the vehicle,
- finding out where the vehicle is located,
- where the vehicle can safely continue so as not to change direction and speed,
- what needs to be done to ensure that the vehicle reaches its desired destination safely,
- journey efficiency and energy savings with regard to the range to the desired destination,
- always get to your destination or charging station [2,3,5,10].

Types of navigation systems for AGV:

- Magnetic tapes

Magnetic tapes stick to the floor, and a vehicle equipped with magnetic sensors follows the tape. The disadvantage of magnetic tapes may be the possibility of damage or tearing off the tape itself. This is a fixed route. There must be no obstacles on this route. Mostly it is an addition to this navigation to laser navigation. The advantage is the easy change of the route of the vehicle. Just remove the tape and a new one will stick to the new route.

- Magnetic points

This method of navigation is very similar to magnetic tape. Instead of tape, individual magnetic points are placed on the vehicle route. There is a magnetic sensor on the car that detects individual points. It is mainly used as a complement to other navigation systems, for example as a control of the main navigation system. The advantages include the ease of removing or adding a new magnetic point.

- Inductive

It consists in guiding the vehicle using an active electrically conductive belt in the floor. Coils are placed under the vehicle. The current that flows through the conductive band in the floor creates different currents on the coils. The deviation of the vehicle from the guide track is recognized by the difference in currents on the coils.

- Optic

In most cases, there is a painted or glued strip on the ground, which is significantly different in color from the floor. An optical sensor located on the vehicle tracks the lane and navigates the vehicle along the route. In addition to the stripe, the optical sensor can also read various optical or code marks, such as code plates. In this way, it is possible to mark places to stop or places that indicate the exact position of the vehicle. The optics must be kept clean, dust-free.

- Laser

The basic principle of this navigation is to send a laser beam to the surroundings and at the same time count the time it takes for this beam to come back. Based on this information, it calculates the distance of the object that is located in the space scanned by the scanner. The great advantages of laser navigation are accuracy and ease of installation. Maintenance is also easy. It is sufficient to keep the reflective points and the laser navigation system clean. Laser navigation can be seen on **Figure 1** [3,7,8,9,10].

Figure 1 AGV with laser navigation [4]

3. FIRE TRUCK AT THE COKE PLANT

AGVs are also widespread in the metallurgical industry. In this sector, vehicles are mainly used for the transport of very heavy materials such as liquid iron, steel coils, steel semi-finished products, coke and coal. Burning coke can be seen on **Figure 2**. In the sequence are the following steps:

1) Ride to the chamber – In the coke battery chamber, the coke production process takes place. As soon as the necessary time for production has passed, it is necessary to push the coke out of the chamber onto the fire truck.
2) Coke pushing – The ejection machine inserts the discharge rod into the chamber and starts pushing. After the discharge rod reaches a certain percentage of insertion, the fire extinguisher starts moving. At the moment when the pushing of the coke is finished, the sequence switches to the next step.

3) Driving under the extinguishing tower – At this stage, the fire truck is loaded with several tens of tons of glowing coke, which usually starts to burn in the air. The fire truck will now start and head under the fire tower, which is located at the end of the track.
4) Extinguishing and dripping – As soon as the car reaches the desired position, extinguishing starts automatically. During extinguishing, water is released from the extinguishing tower, which "showers" the coke on the wagon, thereby extinguishing the flames and sharply lowering the temperature of the coke. In the event that extinguishing is not started within a certain time, the fire truck will trigger an alarm and drive to a position further away from the extinguishing tower. Successful extinguishing of the coke is followed by drip, during which the car stands and waits for water to drain.
5) Ramp Ride & Ramp Tilt – There are several ramps at the coke plant and the program selects depending on which ramp is free of the desired ramp. In the last step, the ramp is tilted, the cycle is then switched to the first step and repeated.

Dust and dirt are the biggest enemy of optical systems. It is necessary to often get rid of dust from these devices. Another complication is the possible damage to electronic devices after dust enters the electronics, or the increased temperature from the metallurgical environment to the electronics may play a role. In metallurgical environments, it is not advisable to use optical and laser navigation [8].

Figure 2 Burning coke [own processing]

4. DESIGN OF SAFETY EQUIPMENT

The area of the coke battery and the surroundings of the fire extinguishing vehicle yard is bounded by a safety fence that prevents unauthorized persons from entering the track during the operation of the fire extinguishing vehicle in automatic mode. The controller was selected by the Simatic S7 PLC. For the model example to secure, light barriers were selected. Access to the fence is possible through six gates (B1-B6), five gates (V1-V5) or one barrier (Z1) see **Figure 3**. On the gates, gates and gates there are beacons signaling the secured or unlocked space. It is possible to enter the area of the yard only after switching off the automatic mode of the fire extinguishing vehicle and unlocking the space. The fence is drawn in green. Gates, gates and barriers in this case is a green rectangle. The operator has the opportunity to monitor whether the fencing is secured or unlocked and is able to manually secure and unlock the entire space or individual gates, gates, or barriers. Fencing can be controlled in several ways. One of the options is to manually control each part of the fencing separately. Another control option that acts as the primary control is to control the fencing through two buttons, namely "Unlock the space" and "Secure the space" as in **Figure 3**.

After pressing the "Odjistit prostor" button, the command is flipped to logical 1 and remains so until all elements of the fencing are unlocked. If there was indeed a release of all elements by fencing, the text with the red background "Odjištěno" was changed. Similarly, the "Vše odjištěno" light was colored red. If the operator presses the "Zajisti prostor" button, there will be a five-second delay and green signals will light up regarding the request for security. Securing is possible only if no fencing alarm is active. After 5 seconds, the text changes to green and "Zajištěno". Operation of the fire extinguishing vehicle is possible only with a fully secured area of fencing. The program constantly checks that all elements are closed and secured. In the event that a person passes, for example, through a light barrier in gate 1, an alarm and a warning about unauthorized entry for a specific element of fencing will be triggered. With the alarm triggered for a specific element, the combined alarm is also activated. This is transmitted to the fire truck and causes the activation of the emergency stop. Simultaneously with the activation of the combined alarm, the fencing is unlocked. Another very important part of the program is the control of communication between the PLC and the control computer, the so-called watchdog. In the event of a communication failure, the fencing is automatically unlocked on the PLC side and thus the automatic operation of the fire extinguishing vehicle is stopped. Next, the notification will be displayed under the "Fence alarm confirmation" button, where the text " Porucha komunikace s PLC " will begin to flash.

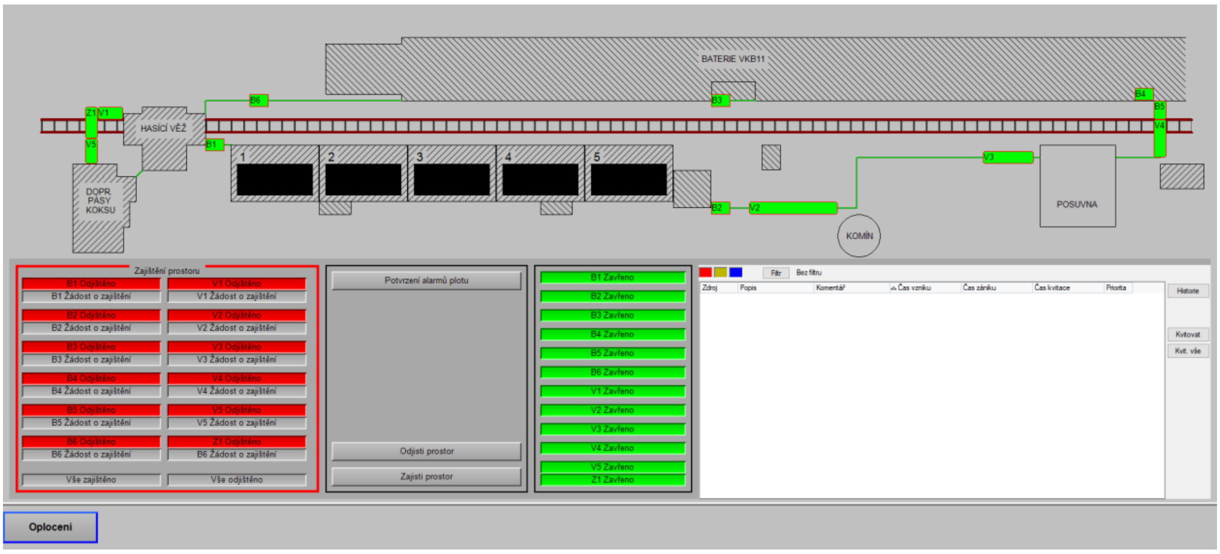

Figure 3 Visualization of fencing [own processing]

Use of machine vision of safety area

Another option to ensure safety is the use of machine vision. Machine vision is most commonly used in industrial automation for product inspection. This kind of control replaces the human eye of the operator in a given position. Hardware includes sensors, sensors, image capture cameras, lighting for cameras, screens for displaying the output image, computers, etc. In addition, software and algorithms are needed to process data streams from cameras. In this part, the possibility of using machine vision to improve the safety of the track area in which the automatically steerable fire extinguishing vehicle moves was tested. The fire truck on which the cameras are placed is constantly moving from one side of the coke plant to the other. It was necessary to add color recognition of the workers' protective clothing and filter out the surrounding colors. Several pixels were selected from the workers' clothing (blue and green) and according to the resulting range of the RGB color model, which corresponded to the protective clothing, the surrounding color was filtered out. The system correctly recognized an approaching worker in the track environment. Another possible solution that could be considered is to add a pattern matching function. The pattern matching process consists of two stages: learning and comparing. During the learning phase, the algorithm is configured so that the programmer takes several pictures of a person wearing protective clothing. These slides form the template for the matching feature.

During the comparison phase, the algorithm compares the image with the learned pattern. The algorithm then finds matches located in the area of the inspected image.

5. CONCLUSION

The theoretical part described the types of automatic vehicles used in the automated industry. The theoretical part ended with a description of various types of navigation for automatically steerable vehicles in the metallurgical industry. In the next section, the working cycle of the fire extinguishing vehicle in automatic mode was described. For the practical part, the proposal to ensure safety in the vicinity of the automatically controlled fire extinguishing truck at the coke plant was solved. A PLC was used to control the fencing. Visualization and control of the fencing was provided by the Promotic visualization program. The fencing control was tested on a test PLC in simulation mode. Another proposal was security by recognizing the difference in the image using machine vision in the Matlab software environment. This option was first successfully tested on photos taken from the home environment. This was followed by testing on photographs taken from cameras in an industrial environment using color filtration. The algorithm was able to detect the difference between images without a worker and with a worker. Color filtering removed color from the image that did not match the color range of the worker's protective clothing. With such an algorithm, it is a condition that workers wear protective clothing of green and blue colors.

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