Development of the method of aggregation to determine the current storage area using computer vision and radiofrequency identification

A Astafiev, A Orlov and D Privezencev
Vladimir State University, Vladimir, Russia

e-mail: Alexandr.Astafiev@mail.ru

Abstract. The article is devoted to the development of technology and software for the construction of positioning and control systems in industrial plants based on aggregation to determine the current storage area using computer vision and radiofrequency identification. It describes the development of the project of hardware for industrial products positioning system in the territory of a plant on the basis of radio-frequency grid. It describes the development of the project of hardware for industrial products positioning system in the plant on the basis of computer vision methods. It describes the development of the method of aggregation to determine the current storage area using computer vision and radiofrequency identification. Experimental studies in laboratory and production conditions have been conducted and described in the article.

1. Introduction
Currently, due to the need of industrial development and the implementation of international quality standards the introduction of new technologies to control product movement is required. Implementation of such control is possible through introduction of automatic identification and recognition systems. The degree of perfection of the product movement control system depends on the efficiency of production in general. Therefore, the solution of control problems in industrial plants, consisting in the development of new and improvement of existing methods and means of information processing, in order to increase the efficiency of the production of motion control systems is essential.

A large number of companies, both domestic and foreign markets hardware and software solutions have long been engaged in the development of such systems. However, the currently existing solutions allow you to automate industrial processes in which a product is transported next to a stationary sensor (eg, a conveyor line with permanently mounted image sensor), or sensor control is performed manually to identify stored products (eg, hand-held portable barcode readers). Use existing systems for more complex tasks, where the transportation of goods is carried out using several routs (eg, transport truck), or using the manual method of identification is technically impossible or contrary to the rules of safety, do not allow to automate the process of monitoring the movement of products due to low reliability of the results.

One of these tasks is to develop a system of automatic identification of markings on metal pipes on the example of pipe electric welding shop № 3 (Welding Shop №3) of OJSC «Vyksa Steel Works» (VSW). Storage of pipes at Welding Shop № 3 made by the organization «heaps» of the same type of products in the two types of warehouses: indoor (inside the plant premises) and open (outdoor...
Transportation of pipes is performed in 5 different ways: conveyor, overhead crane with hooks, a bridge crane with electromagnets, vacuum loader and street autoloader with hooks. Pipes come to the shop on the conveyor belt, and leave it in rail cars.

The main difficulties of implementing automatic control are:

1. The presence of 5 different ways to transport products, which involves the development of a universal approach for all types of transportation.
2. The presence of both indoor and outdoor spaces, which involves the development and use of algorithms to artificially shade and lighten the image, by using methods of digital image processing.
3. Inability to use manual methods of data collection due to safety rules (need to stand clear of the crane and the loader boom).
4. Use the visual markings on the tubes is complicated due to their distortion from friction between the pipes.
5. The use of radio-frequency labels is not possible due to lack of credibility, since the products are made of metal, which badly distorts radio waves.
6. The hardware is to be designed as a stand-alone installation, placed on a transport device without making any changes in their structure (as this is against the Rosstandart rules) and remote units (as during the rise / descent of traverse the pipes are beating against the sides of the trucks and each other).

The main application purpose is to develop a method for automatic identification of pipes based on the technology of mathematical data and software aggregation of the digital processing of heterogeneous features a unified point of images and statistical analysis of radio frequency identifiers, which will automate the process of motion control products on the Welding Shop №3 OJSC "VSW".

Automation of pipe movement control will quickly and accurately obtain information on the status of storage, reduce the risk of regrading and pipe loss, as well as increase the efficiency of the search and transporting a given product to the place of storage or shipment.

2. Development of the project of hardware for industrial products positioning system in the plant on the basis of computer vision methods

Based on the functional requirements of the system, it can be concluded that the developed system should work equally well on various transport devices and in different weather and lighting conditions. Therefore, it is advisable to develop a custom universal video device to obtain homogeneous data for use in a variety of production environments.

As the practice shows the most "narrow" place of such systems is the communication channel between the video sensor and video data processing unit. Therefore, it is advisable to place a video processing device in the vicinity of the video sensor and transfer already processed and recognized identifiers of transported products to the warehouse server.

Implementing such systems sharply raises questions about the presence of power supply and communication channel. To address the question of power it was decided to supply the device with independent replaceable batteries. Data transfer is made using Wi-Fi wireless networks, which makes the inclusion of Wi-Fi device transmitter mandatory.

Given all of this video device of automatic detection and marking identification should include:

1. The vision sensor.
2. Microcontroller.
3. Power supply.
4. Wi-Fi transmitter.

General view of the device can be represented in a pattern (Figure 1):
The hardware implementation of the video device for automatic detection and marking identification may consist of a single device, which includes all necessary elements of the system (for example, smartphone or terminal), or consist of individual functional units.

Necessary conditions of work of automatic marking identification system:
1. The presence of sustained and stable Wi-Fi coverage in the territory of operating of identifying equipment.
2. The regular replacement of power supply elements and equipment maintenance.
3. Bar coding markings stamped onto the tube circumference (at least 4 places).

Detection, localization and identification of markings on industrial products is performed using the algorithms described in the publications [1–3].

3. Development of the project of hardware for industrial products positioning system in the territory of a plant on the basis of radio-frequency grid
As the basic data for the implementation of tracking of industrial products emerge in the course of its movement through the territory of the plant, it is expedient to develop a hardware project to receive and process all the data. The main types of traffic information is the information about who moves the products, how and its route. Production and processing of this information will allow to organize a permanent automatic traceability of industrial products on the plant.

The paper proposes the development of a stand-alone device, consisting of a reading, processing and transmission of information equipment. The developed device is mounted on the transport device, and to ensure the positioning, plant territory is marked with RFID tags, thus creating a radio frequency grid.

Thus, the hardware part of the system can be divided into 5 levels:
1. The RF tag for labeling storage areas.
2. Equipment to read RFID tags.
3. Equipment for collecting and processing statistical data.
4. The equipment for the transmission of data to the enterprise server.
5. Software and hardware that is used by the company.

Laboratory prototype was developed for testing the project hardware industrial products positioning system on the territory of the enterprise on the basis of radio-frequency grid for experimental studies. Laboratory prototype consists of a microcontroller, a manual RF reader, power supply unit and a laptop (Figure 2).
4. Development of the method of aggregation to determine the current storage area using computer vision and radiofrequency identification

The work of algorithms to determine the current storage area in a production environment is highly dependent on the presence of various kinds of interference, introducing distortions in the raw data set for analysis. In view of this, aggregation algorithms based on different technologies and approaches will improve the accuracy of their results.

If the algorithm for determining the current storage area based on methods of computer vision returns the result of the current position \( C_{tv} \) and evaluation, showing the accuracy of the calculations \( ptv \), and the algorithm to determine the current storage area on the basis of methods of RFID returns the current position \( Crfid \) and evaluation, showing the accuracy of the calculations \( prfid \), then the methodology of aggregation algorithms that determine the current storage area can be represented by the following set of steps:

1. Obtaining data from algorithms to determine the current storage area on the basis of methods of computer vision (\( C_{tv}, ptv \)) and radio frequency identification (\( Crfid, prfid \)).
2. Comparison of the results of \( C_{tv} \) and \( Crfid \).
3. If \( C_{tv} = Crfid \), then one of the values of \( C_{tv} \) or \( Crfid \) is transferred to PCS warehouse database as an identifier of the current storage area.
4. If \( C_{tv} \neq Crfid \), then ID value of storage area with the higher accuracy of the calculations is transferred to PCS warehouse database. In this case, the field is set in the database which shows that the results of determination of the storage area should be refined.
5. Data on the current storage area are sent to warehouse database.

The work of this method can be represented by the following formula:

\[
(C_{db}, p) = \begin{cases} 
(C_{tv}, 0), & \text{IF } C_{tv} = C_{RFID} \\
(C_{tv}, 1), & \text{IF } C_{tv} \neq C_{RFID}, ptv > prfid \\
(C_{RFID}, 1), & \text{IF } C_{tv} \neq C_{RFID}, ptv < prfid 
\end{cases}
\]

where \( C_{db} \) – the storage area identifier, recorded in the warehouse database; \( p \) – the need for additional control of the recorded information flag, 1 – is necessary to monitor, 0 – data is correct.

The generalized scheme of the technique for algorithm aggregation to determine the current storage area based on methods of computer vision and RFID is represented in a pattern (Figure 3):
Refinement of the result for current storage area can be done in two ways:
1. Manual mode by doing inventory in a warehouse or in a specific storage area.
2. Automatic mode by checking the correctness of the specified data in the subsequent transportation of industrial products, whose position has been determined inaccurately.

The choice of method to clarify the current storage area is done by enterprise staff through establishing the rules of work in the storage area.

5. Conclusion

The article is devoted to the development of technology and software for the construction of positioning and control systems in industrial plants based on aggregation to determine the current storage area using computer vision and radiofrequency identification. It describes the developed of the project of hardware for industrial products positioning system in the territory of a plant on the basis of radio-frequency grid. It describes the development of the project of hardware for industrial products positioning system in the plant on the basis of computer vision methods. It describes the development of the method of aggregation to determine the current storage area using computer vision and radiofrequency identification. Experimental studies in laboratory and production conditions have been conducted and described in the article.

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