Development of an algorithm for forecasting and preventing emergency situations in industrial traffic control systems based on data analysis of multi-code identifiers

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Abstract. This article proposes a method for controlling the movement of industrial products based on data from multi-code identifiers using the algorithm for forecasting and preventing extraordinary situations. In the course of the work, possible extraordinary situations arising in the process of displacement were analyzed. Also on the basis of the developed algorithms, simulation modeling was carried out, according to the results of which it was shown the effective use of this method for controlling the movement of products in industrial enterprises.

Keywords: multicode labeling, movement control, technical vision, radio frequency identification, RFID, 1D / 2D codes.

1. Introduction

At present, for the identification of industrial products, product marking is mainly used with the help of barcode [1] or radio frequency tags [7; 8; 9]. These solutions do allow you to shorten the time of searching for a product on the territory of the enterprise, however, they are not without shortcomings, since they are not able to forecast possible supernumerary situations.

For example, when moving a load, the label is not always in the sensor's field of view, so that the marking is not visible to the reader or person. Although it is worth noting that for security reasons, people in such jobs are practically not involved. Also, the marking, during transport or movement on the conveyor belt, may be poorly secured, as a result, it may fall off or fall onto another product. Proceeding from this, it can be concluded that for reliable product identification, several markings on one product should be used, the number of which can depend on the geometric parameters of the object. To accurately control the location of products, you should use the algorithm for finding errors in the occurrence of abnormal situations (for example: when several labels identify one label from several possible ones), which will promptly make a decision to the operator and eliminate the violation.

The purpose of this work is the development of an algorithm for forecasting and preventing emergency situations in traffic control systems for industrial products based on the analysis of data of multi-code identifiers, during which it is necessary to perform the following tasks:

- conduct a comparative analysis of analogue systems;
- develop a simulation model of the process of moving products;

- to formulate freelance situations;
- develop an algorithm for forecasting and preventing extraordinary situations;
- carry out an experimental study using simulation tools.

2. Overview of analogues

At the moment, to implement the goal, there are several similar solutions. We will perform a comparative analysis of these analogs, as a result of which we can conclude which system is more profitable to use in the future:

1. VITRONIC - automatic recognition system is used to read barcodes in various industries. The results of a comparative analysis of this system are given in Table 1:

Table 1. Advantages and disadvantages of using VITRONIC.

VITRONIC	
Advantages of use	Disadvantages of use
Recognition of different types of codes (1D, 2D)	The implementation of an algorithm for monitoring contingencies is required
Reading OCR (serial numbers, batch numbers, articles, etc.)	
Multi-code reading	

2. OptiCode is an industrial scanner for high-speed barcode reading. Advantages and disadvantages are presented in Table 2:

Table 2. Advantages and disadvantages of using OptiCode.

OptiCode	
Advantages of use	Disadvantages of use
Tracking the product from the moment of receipt to the warehouse	The implementation of an algorithm for monitoring contingencies is required
Scanning barcodes from a long distance (15m)	
Allows you to position the camera on cranes or carts	
	No multi-code reading support

As a result of the comparative analysis of the presented analogs, it can be concluded that these solutions are not entirely suitable for use, since they basically do not have an algorithm for forecasting and preventing contingencies. In some cases, there is no support for multi-code reading, as a result of which a significant amount of funds will be required for the development, which is unprofitable.

3. Development of a simulation model for the movement of industrial products

At the enterprise every 100 ± 2s there are applications for receiving products. Then the products are moved to storage racks. Processing of such applications takes 180 ± 2s. After the work can move to the neighbouring shelves or the place of shipment. The processing takes 150 ± 2s and 160 ± 4s, respectively. In the case of accepting applications for participation or the remaining applications do not have time to process within a specified period of time, they are automatically lost. It is required to simulate the work by moving industrial goods during one working shift. The scheme of this simulation model is shown in Figure 1.

It should be noted that during the operation of the simulation model, the following contingencies may arise during the transportation of products, which must be taken into account:

1. Supernumerary situation 1 – during the movement of the product, the same marking is read.
2. Supernumerary situation 2 – in the process of identification, a non-existent marking fell into the field of view of the reader.

3. Supernumerary situation 3 – During the transfer to the product, the marking of another object, by mechanical action (marking off) or deliberate action of personnel (intentional re-gluing of the marking) fell on the product.

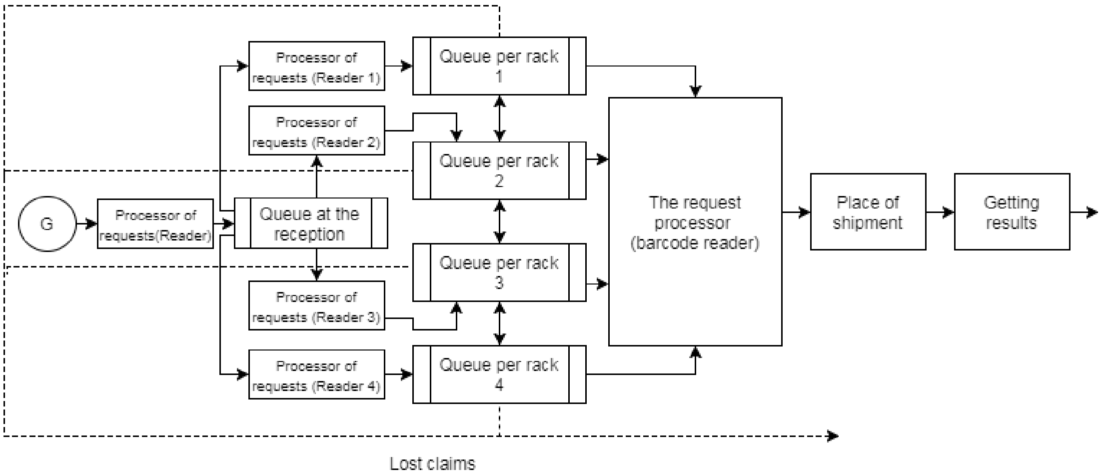

Figure 1. Model outline.

4. Development of an algorithm for forecasting and preventing emergency situations during the movement of products

Consider the algorithm for predicting and preventing emergency situations by steps:

1. When goods arrive at the place of reception, we fix the identified product markings, the time of arrival, and its location.
2. When moving, the time, the current location and location of the rack, to which the product enters, is fixed.
3. Receipt on the rack is the same as in paragraph 1 with the comparison of marks.
4. Moving between the shelves and when entering the place of shipment occurs, in accordance with paragraphs 1-3.
5. If during the movement of the product from the storage areas the same marking is received in the field of view of the reader, the system generates a warning for its verification, which corresponds to an abnormal situation 1.
6. If a non-existent marking has appeared in the field of view of the reader or from another product, we generate a warning, which corresponds to abnormal situations 2, 3.

The flowchart of the algorithm is shown in Figure 2:

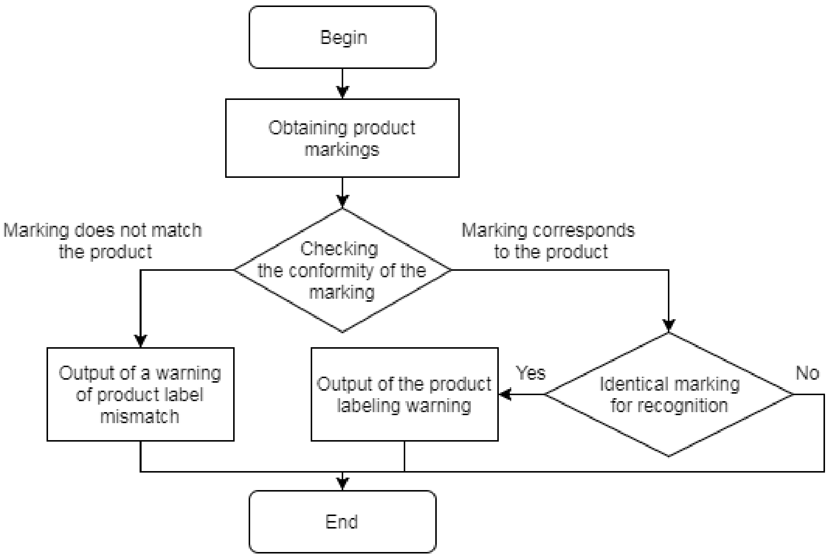

Figure 2. Block diagram of the algorithm being developed.

5. Experimental study

5.1. Description of the experiment

Before the implementation of the algorithm and model, an experiment was conducted to collect all the necessary input data.

The experiment consisted of the following:

1. We took an object of a cylindrical shape, placed on it 4 barcodes. There can be several items, since in real production when moving products with a crane or a conveyor belt, several products are simultaneously received in the field of the reading sensor.

2. With the help of any technical device that allows you to capture an image (for example: a mobile phone camera or a camera), you took a few pictures, on which the products were imaged in different positions (different positions are meant).

3. On the basis of the collected images, a representative sample of the read barcodes was made and all the data entered into the table.

4. As a result of the collected information, the probability of identified markings was calculated, which later allowed modeling and implementing the necessary algorithms.:

5.2. Image analysis

During the experiment, 3 cylindrical objects were taken, on each of which 4 barcodes were attached. For multi-code marking, a Code-11 bar code was used, as shown in Figure 3:

00000001

Figure 3. Example barcode used for marking products.

In order to get a more accurate result, you need to photograph as many different cases as possible. The result is shown in Figure 4:

Figure 4. Example of images taken during shooting.

As can be seen from Figure 4, with different positioning of the object, in most cases 1 or 2 barcodes are identified. It is worth noting that on some images, there were recognized 3 marks on one product, but this result is extremely rare and can be neglected, since the label is practically not visible. Based on the images received, a sample was taken, the results of which are summarized in Table 3:

Table 3. Total number of identified labels.

Image No.	Number of identified barcodes												Unrecognized barcodes
	Pipe 1				Pipe 2				Pipe 3				
	Barcode number on the pipe				Barcode number on the pipe				Barcode number on the pipe				
	00000001	00000002	00000003	00000004	00000005	00000006	00000007	00000008	00000009	00000010	00000011	00000012	
1				1			1	1			1		1
2	1				1			1			1		0
3	1			1			1	1			1	1	0
4				1			1					1	2
…	…	…	…	…	…	…	…	…	…	…	…	…	…
1597			1				1	1			1		1
1598			1				1				1	1	1
1599	1			1				1	1				2
1600		1					1				1		1
Total Recognized	680	240	280	720	80	80	760	760	720	280	400	320	1840
Total	1920				1680				1720				1840

According to the information presented in Table 3, you can find out the numeric data on the recognition of only 1 barcode, 2 or more:

Table 4. Number of read tags on each object.

Option	Number of read tags		
	Pipe 1	Pipe 2	Pipe 3
1 barcode recognized	920	960	1020
2 barcodes recognized	680	640	580
3 or more barcodes recognized	0	0	0

As a result, from the presented tables it is possible to calculate the probability of barcode identification on the product:

1. Probability of recognition of 1 barcode: 66,67%
2. The probability of recognizing 2 barcodes: 33.33%

6. Results of the simulation model work

Based on the scheme of the developed simulation model, presented in Figure 1, it can be seen that each movement of the object is controlled by reading the markings with the help of the handler of applications from the place of receipt of the product to its shipment. In this handler there is a comparison of the markings and further decision-making on the output of messages in the event of abnormal situations during transportation (Figure 5, 6).

The figures show the work of the algorithm for predicting and preventing extraordinary situations. For example, if you take the product number 21, then during the move it can be noticed that on arrival in the rack 1 the reader identified only one marking (barcode number: 2055596). After receipt of the product at the place of shipment, the same marking is observed, resulting in the generation of a message and notification of a possible violation in the marking of the product for the purpose of checking it.

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The process of moving:
10:00:57 | Product ID: 6 Moved to the rack 4 | Recognized: 9880750,9880748
10:00:57 | Product ID: 2 Moved to the place of shipment | Recognized: 1922516,1922517
10:00:58 | Product ID: 11 Moved to the rack 3 | Recognized: 9441368,9441369
10:00:58 | Product ID: 6 Moved to the place of shipment | Recognized: 9880749
10:00:59 | Product ID: 21 Moved to the rack 1 | Recognized: 2055596
10:01:00 | Product ID: 11 Moved to the place of shipment | Recognized: 9441368,9441369
10:01:00 | Product ID: 22 Moved to the rack 4 | Recognized: 9860738
10:01:01 | Product ID: 30 Moved to the rack 4 | Recognized: 9429826,9429825
10:01:01 | Product ID: 35 Moved to the rack 4 | Recognized: 6378369
10:01:02 | Product ID: 21 Moved to the place of shipment | Recognized: 2055596
10:01:05 | Product ID: 64 Moved to the rack 1 | Recognized: 7303325,7303324
10:01:06 | Product ID: 46 Moved to the rack 1 | Recognized: 1054826
10:01:06 | Product ID: 35 Moved to the place of shipment | Recognized: 6378372
10:01:06 | Product ID: 30 Moved to the place of shipment | Recognized: 9429824
10:01:07 | Product ID: 45 Moved to the rack 4 | Recognized: 6363338,6363335
10:01:08 | Product ID: 60 Moved to the rack 1 | Recognized: 9979266
10:01:09 | Product ID: 20 Moved to the rack 2 | Recognized: 7325444,7325445
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Figure 5. Displaying the progress report.

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Displaying system messages:
10:00:57 | Product ID: 4 | Check is not required
10:00:57 | Product ID: 5 | Check marking
10:00:57 | Product ID: 2 | Check is not required
10:00:58 | Product ID: 6 | Check is not required
10:01:00 | Product ID: 11 | Check is not required
10:01:02 | Product ID: 21 | Check marking
10:01:06 | Product ID: 35 | Check is not required
10:01:06 | Product ID: 30 | Check is not required
10:01:10 | Product ID: 45 | Check is not required
```

Figure 6. Displaying system messages during movement.

An example of a general simulation result report is shown in Figure 7:

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Simulation results:
Total number of objects: 100
Recognized objects: 15
1 barcode is recognized: 6
Recognized 2 barcodes: 9
Conformity markings: 7
Inconsistency of markings: 2
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Figure 7. Example of a general simulation results report.

7. Conclusion

On the basis of the work done, it can be concluded that when using several labels for product identification, the probability of recognition increases, since regardless of positioning in any case, 1 mark will be visible to the reader. Based on the results of the input data, an imitation of the operating model was developed using the algorithm for predicting and preventing extraordinary situations. The results of simulation have shown effective use for business and implementation in the enterprise.

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