# Analysis of the Applicability of the Bundle Method for the Construction of Multi-Code Labelings

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**Abstract.** The article presents the results of studies on the applicability of the method of monitoring the integrity of the method of bundles for the organization of multi-code labeling of products in the enterprise. The definition of multi-code marking is given, the purpose of its application is described. A comparative analysis of the integrity control methods has been carried out and their quality indicators are given in the field of organizing the control of product movement. An algorithm for generating multi-code labeling based on integrity control methods, an algorithm for determining falsification and recognition errors are proposed. Examples of generated identifiers are given. The results of the research were expressed in the form of a web application integrated into the online store of the Global33 Group of companies (Vladimir Region, Murom, Kovrov), which is confirmed by the implementation certificate. The purpose of the implemented system is to organize the automatic traceability of the rolls of air-bubble film along the conveyor line.

## 1. Introduction

Currently, due to the need for the development of industry and the implementation of international quality standards, the introduction of new high-tech technologies to control the movement of products is required. The implementation of such control is possible through the introduction of automatic identification and recognition systems. The efficiency of production as a whole depends on the degree of perfection of the motion control system (ACS) performance of products. According to the standard GOST R 56542-2015 [1], there are 9 methods of non-destructive testing, of which 2 have found wide practical application in ACS: radio frequency identification and technical vision. Both approaches have their advantages and disadvantages, but the main requirement for the ACS products built using any of the technologies is the direct visibility of the marking by the readout sensor.

Due to this limitation, most of the developed automatic ACSs operate on the principle of a stationary mounted sensor, where the movement of controlled products is carried out strictly along it. Such ACS are widely used in industrial plants with conveyor lines. In cases with more complex logistical mechanics, the reliability of such systems is extremely low. In practice, more complex SKDs are used, in which the sensors are located on the transporting devices themselves, however, the identification accuracy in them often does not exceed 95%, and the construction of logistic routes occurs with the condition of turning the marking towards the reading device, which increases the time for transportation and requires more challenging their work [2].

In order to reduce the time for transportation and installation of additional equipment at enterprises, it is proposed to use the multi-code labeling approach. When using this approach, products are marked with a set of labelings sufficient to ensure that at any turn to the sensor at least one of the identifiers is in its field of view.

Using the multi-code labeling approach creates artificial redundancy of information, however, if the identifiers of the multi-code marking are “linked” to each other, then additional data can be extracted to analyze the process of controlling the movement of target objects [3-4].

Based on the foregoing, the development of an approach for multi-code marking of target objects is an actual scientific and technical problem.

The aim of the work is to study the possibilities of using the bundle method for the formation of multi-code labelings of dynamic objects for automating their identification in the process of stochastic movement.

To achieve this goal it is necessary:

1. to analyze the subject area. Consider the basic concepts and definitions;
2. to review and analyze business processes, the use of multi-code labeling in which will increase the proportion of successful identification;
3. to consider the main methods and approaches to ensure the integrity of identifiers;
4. develop an algorithm for generating multi-code labeling based on the bundle method;
5. run the software implementation of the developed algorithm and conduct experimental studies.

## 2. Research Method

The development of information technology inevitably affects a large number of business processes in all fields of activity. From all these business processes, from the point of view of the use of product labeling, two major areas of research can be distinguished: the control of the movement of objects in industrial enterprises and the accounting of inventory values (TMS) in retail.

From a retail point of view, a labeling of inventories is necessary to protect against theft and to identify information about the object. The solution of these tasks is often made using two different technologies: radio frequency identification to protect against theft and a vision system for identifying goods and materials by graphic code (barcode, QR code) [5-10]. Combining these approaches leads to the need to use at least two labels on one product (another marking is the product's bar code applied by the manufacturer). Thus, for marking goods and materials in modern retail outlets, multi-code markings, whose potential has not yet been revealed, have long been used (Figure 1).


**Figure 1.** An example of multi-code labeling in modern retail trade enterprises.

From the point of view of industrial enterprises, industrial products are subject to marking in the process of their production or after their transfer to the storage area, in order to control their movement. Control of the movement of products in the enterprise allows to increase the efficiency of loading and unloading operations and to obtain more detailed information about the technological process as a whole [11-13].

## 3. Overview of Methods and Algorithms for Organizing Data Integrity Management

Information integrity is the ability of a computer or automated system to ensure the immutability of information under conditions of random and (or) deliberate distortion (destruction) [14].

Also common is the definition of information integrity as the absence of inappropriate changes. The meaning of the concept of “inappropriate change” is revealed by D. Clark and D. Wilson in their article “A comparison of Commercial and Military Computer Security Policies”: no user, including an authorized user, should be allowed such changes in data that will entail for their destruction or loss [15].

Under the threat of violation of integrity refers to any intentional change of information stored in a computer system or transmitted from one system to another. When cybercriminals intentionally alter information, it is said that the integrity of information is violated. Integrity will also be compromised if an unauthorized change is caused by a random software or hardware error.

The main integrity control mechanisms include:

1. check number;
2. the method of checksums;
3. bit parity;
4. bundle method;
5. the method of "cyclic redundancy code;
6. unidirectional hashing functions.

The paper proposes to organize the relationship of identifiers that are part of multi-code marking, based on rainbow tables of integrity control methods. To do this, it is necessary to consider the existing methods of integrity control and conduct a preliminary assessment of the possible number of sets of identifiers and their number in the set, depending on the original alphabet and the length of the identifiers. Table 1 shows the values of the possible number of sets and identifiers in them when using the alphabet of 10 characters: 0...9.

**Table 1.** Values of the possible number of sets and identifiers in them when using the alphabet in 10.

| Integrity control method | Check number | Parity bit | Bundle method | Cyclic redundancy code (CRC) |
|---|---|---|---|---|
| Possible number of sets | 10, 100, 1000 etc. | 2 | 10, 100, 1000 etc. | CRC-8: 255<br>CRC-16: 56 535<br>CRC-32: 4 294 967 296<br>etc. |
| Possible number of unique identifiers | 10, 100, 1000 etc. | 10, 100, 1000 etc. | 10, 100, 1000 etc. | 0...∞ |

Based on the analysis performed, it can be concluded that the control number, the bundle method and the cyclic redundancy code are potential for consideration by the integrity control methods. The hash function methods are too complex to build rainbow tables, and the parity bit method has too few possible sets.

## 4. Analysis of the Applicability of the Method of Bundles for the Generation of Multi-Code Markings

The main approach used in the bundle method is that the checksum is considered not for the whole value, but for its component parts. The component part of the identifier is obtained by breaking it up into several parts of equal size (Figure 2). By varying the number of component parts of an identifier, it is possible to change the number of unique sets of these identifiers, i.e. multicode markings.

The number of characters in the label (l) and the number of bundles into which it is broken it is broken (b) is set by the user. The number of sets of labels (C), united by one checksum of bundles is calculated:

$$C = \begin{cases} A^{l/b}, if\ l \mod b = 0 \\ it\ is\ not\ computable, otherwise \end{cases},$$

where A is the alphabet of label.

The number of unique *cb* values is calculated as:

$$cb = A^{b}.$$

Thus, by using an alphabet of 10 characters (0-9) and a maximum length of 20 characters, you can get up to 1,000,000,000,000,000 sets of labels with 100 unique identifiers each. The calculation results are summarized in Table 2.

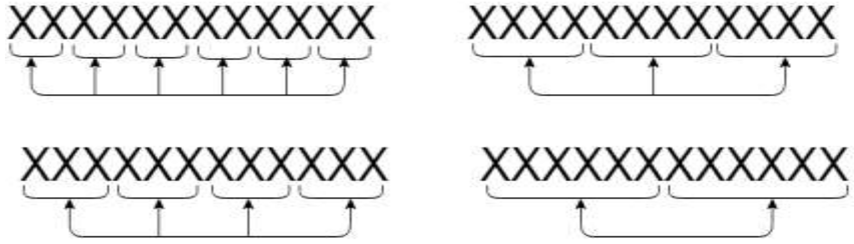

**Figure 2.** The division of the identifier into components.

**Table 2.** The results of calculating the number of sets of tags and identifiers in them.

| Code length | The number of characters in bundles | Number of characters to store checksums of bundles | Number of label sets |
|---|---|---|---|
| 4 | 2 | 100 | 100 |
| 6 | 2 | 100 | 10 000 |
| | 3 | 1 000 | 1 000 |
| 8 | 2 | 100 | 1 000 000 |
| | 4 | 10 000 | 10 000 |
| 9 | 3 | 1 000 | 1 000 000 |
| 10 | 2 | 100 | 100 000 000 |
| | 5 | 100 000 | 100 000 |
| 12 | 2 | 100 | 10 000 000 000 |
| | 3 | 1 000 | 1 000 000 000 |
| | 4 | 10 000 | 100 000 000 |
| | 6 | 1 000 000 | 1 000 000 |
| 14 | 2 | 100 | 1 000 000 000 000 |
| | 7 | 10 000 000 | 10 000 000 |
| 15 | 3 | 1 000 | 1 000 000 000 000 |
| | 5 | 100 000 | 10 000 000 000 |
| 16 | 2 | 100 | 100 000 000 000 000 |
| | 4 | 10 000 | 1 000 000 000 000 |
| | 8 | 100 000 000 | 100 000 000 |
| 18 | 2 | 100 | 10 000 000 000 000 000 |
| | 6 | 1 000 000 | 1 000 000 000 000 |
| | 9 | 1 000 000 000 | 1 000 000 000 |
| 20 | 2 | 100 | 1 000 000 000 000 000 000 |
| | 4 | 10 000 | 10 000 000 000 000 000 |
| | 5 | 100 000 | 1 000 000 000 000 000 |

## 5. Algorithm for Generating Multi-Code Labeling using the Bundle Method

To determine the parameters of the calculation of labels by the bundle method, combining sets of identifiers, it is necessary to perform their initial optimization. To do this, based on the practical problem to be solved, it is necessary to determine:

Alphabet Marking (Ac).

The number of product items to be a one-time identification (Dc).

The number of labels in the set (Cc).

Based on the information received, it is possible to determine the optimal values of b and l. The value of the variable b is chosen based on the fact that the number of combinations Ab must significantly exceed the required number of labels in the set Cc. The value of l is chosen based on the fact that the number of unique sets significantly exceeds the number of units of products subject to a one-time identification of Dc, as well as l mod b = 0. From the point of view of mathematics, this can be represented as Equations:

$$b\left|(A^b >> C_C)\,\&\,(l \mod b = 0),\ l\right|(A^{l/b} >> D_C)\,\&\,(l \mod b = 0).$$

To generate a set of identifiers, the following sequence of steps is performed (Figure 3):

1. the number of the last generated set is determined (either from the database or stored in the system). If the number is not defined, the value of the number is reset to zero (this means that the first set is generated). If the number is determined, then the number of the generated set is formed by adding one. The number of the generated set is recorded in the database or registered in the system;
2. the part identifier is determined by the number of the generated set (the number itself can be an identifier or be counted by simple mathematical expressions, for example, addition);
3. under the set number, the required number of randomly generated unique identifiers is selected according to the rules of the bundle method;
4. the obtained data is recorded in the database and attached to the product.

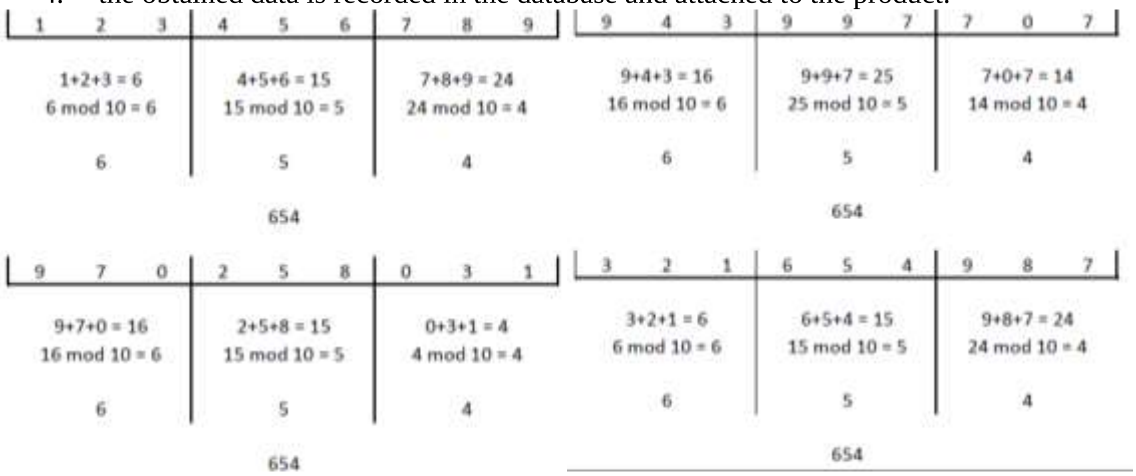


**Figure 3.** An example of multi-code marking.

An example of multi-code marking is presented in Figure 4:

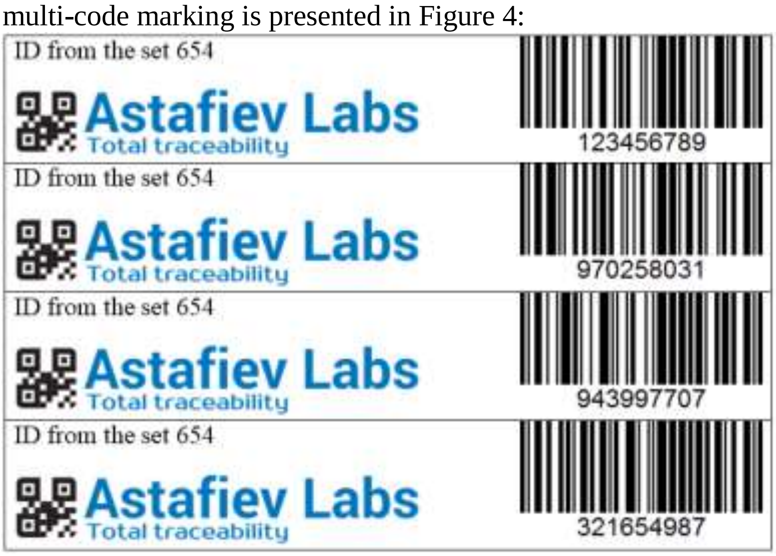


**Figure 4.** Example of multi-code marking.

## 6. Development of an Algorithm for Self-Control and Correction of Identifiable Labels

In the course of work on the project, a variety of integrity control methods were considered for linking identifiers with each other. After conducting experimental studies, it was concluded that the approach that uses a combination of these methods is most effective. This algorithm is intended for the analysis of unique multi-code labeling interconnected by a numerical sequence and allows you to find all the other numbers of this object.

In the systems for controlling the movement of products, it is necessary at each stage of movement to identify objects that are in the field of view of reading devices. However, if several numbers fall in the field of view of a scanner or camera, the question arises how to prove that this number belongs to this object. Consider the principle of operation of this algorithm in steps:

1. generation of a unique number;
2. check the generated number for existence in the database;
3. if the number does not exist, the creation of a cyclic redundancy code (CRC), and a control number (number + CRC) obtained during the operation of the Moon algorithm, as well as a unique value, occurs, otherwise items 1 and 2 are performed;
4. the resulting numeric values are connected together in one number using a separator;
5. the generated number is loaded into the database;

In the form of a flowchart, the algorithm is as follows:

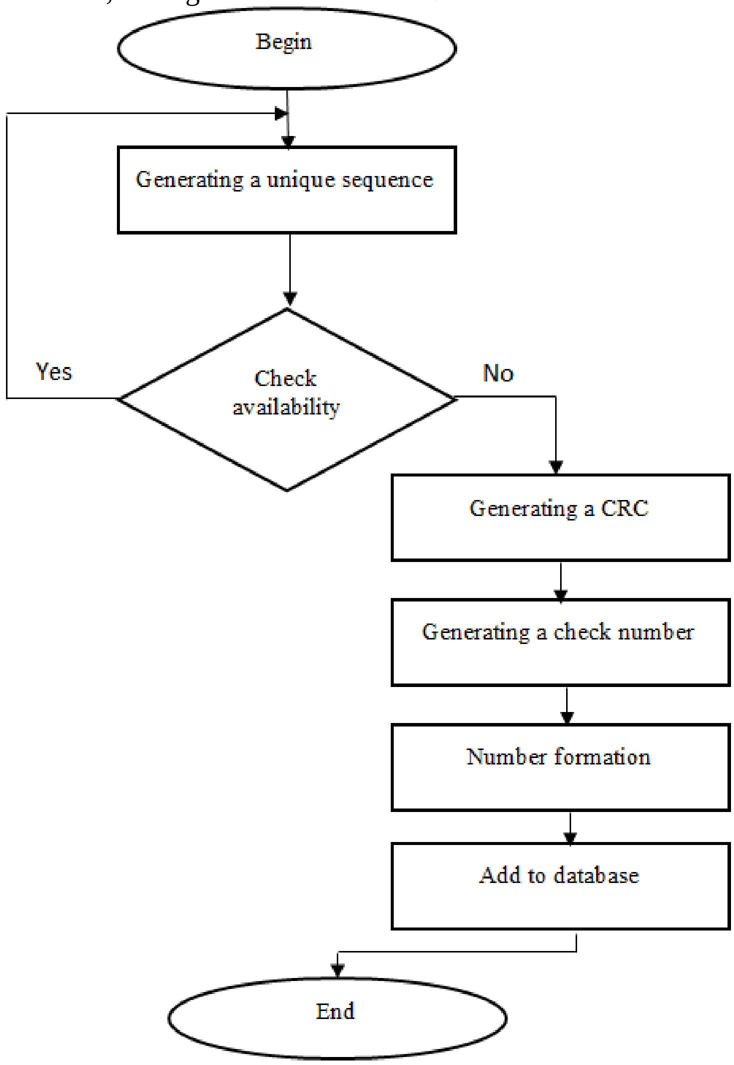


**Figure 5.** Block diagram of the algorithm for generating unique numbers.

A cyclic redundancy code and control number are needed to check the identified number for changes in marking by mechanical means or if the number is not recognized correctly.

Consider the algorithm for checking multi-code identifiers step by step:

1. read labels that fall within the visibility range of the scanner or reader;

2. each number is checked for its integrity, that is, the sequence of each marking block is checked;

3. if the marking is correct, that is, its integrity is not broken, the labels are checked among themselves;

4. if the marking does not match any of the blocks, it is considered that the integrity of the marking is violated (changing one of the symbols, etc.);

5. if during the verification of labels their blocks with information differ from each other, then the labels belong to different products.

Clearly, the verification process can be represented as follows.

Figure 6 shows examples of the work of the developed algorithms. In the first case, two identifiers of different products were incorrectly (or intentionally) applied to the product. In this case, the information blocks do not converge, on the basis of which it can be concluded that accidental or deliberate falsification of identifiers has occurred.

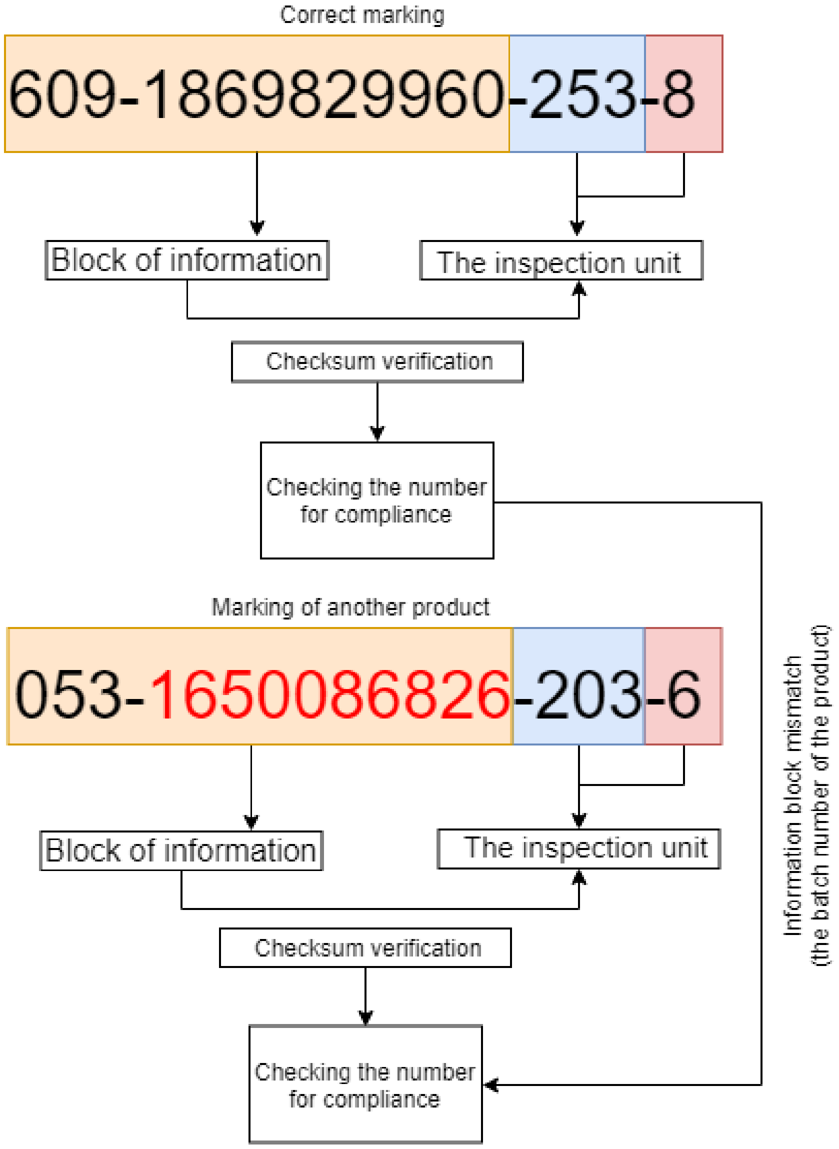


**Figure 6.** Example of verification process.

In the second example (Figure 7) there is a more difficult question. Suppose that two identifiers fell into the field of view of the reading sensor, but one of them was recognized with an error. In this case, verification of checking blocks takes place. With the help of additional analytical actions, you can determine the location of the error and take appropriate action.

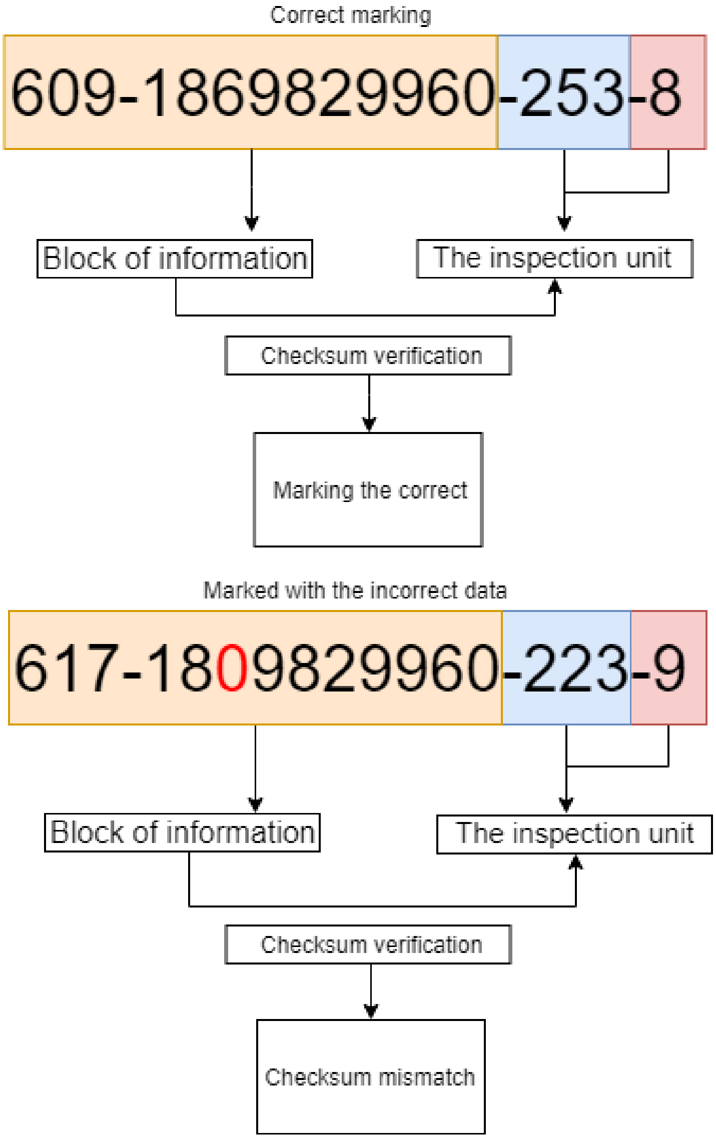


**Figure 7.** Example of errors of readings.

## 7. Conclusions

In the course of the project, an analysis was made of the applicability of the bundle method for organizing multi-code marking. The results were a mathematical model for calculating the composition of multi-code labeling and an approach to optimizing the approach used for the needs of a particular enterprise, based on production volumes and product labeling requirements.

An algorithm for generating multi-code labeling is considered and approaches to self-control and correction of identification results are considered. An approach has been developed to determine the falsification of marking and identification errors of a reading sensor.

The results of the research were expressed in the form of a web application integrated into the online store of the Global33 Group of companies (Vladimir Region, Murom, Kovrov), which is confirmed by the implementation certificate. The purpose of the implemented system is to organize the automatic traceability of the rolls of air-bubble film along the conveyor line.

## 8. Acknowledgments

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