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I. Sh. NEVLIUDOV, O. M. KLYMENKO, V. V. YEVSIEIEV, S. S. MAKSYMOVA

IMPROVEMENT OF THE ENCODING INFORMATION METHOD FOR PHARMACEUTICAL PRODUCTS QR-CODES DURING SORTING ON A ROBOTIC CONVEYOR LINE

The article presents an improved encoding information method for QR-codes, designed to increase the efficiency of robotic conveyor lines for sorting pharmaceutical products. The proposed solution is based on the use of the redundancy operator and random permutation algorithms, which allows reducing the number of errors during reading, increasing the resistance of QR codes to mechanical damage and reducing processing time. The conducted studies demonstrate an increase in sorting accuracy by 35% and a decrease in the frequency of failures by 25%, which provides significant optimization of production processes and improved reliability of automated systems.

Keywords: QR-code, Robotic Conveyor Line, Pharmaceutical Products, Information Encoding, Redundancy Operator, Resistance to Damage, Automation, Sorting.

І. Ш. НЕВЛЮДОВ, О. М. КЛИМЕНКО, В. В. ЄВСЄЄВ, С. С. МАКСИМОВА

УДОСКОНАЛЕННЯ МЕТОДУ КОДУВАННЯ ІНФОРМАЦІЇ У QR-КОДАХ ФАРМАЦЕВТИЧНОЇ ПРОДУКЦІЇ ПРИ СОРТУВАННІ НА РОБОТИЗОВАНІЙ КОНВЕЄРНІЙ ЛІНІЇ

У статті представлено вдосконалений метод кодування інформації у QR-кодах, розроблений для підвищення ефективності роботи роботизованими конвеєрними лініями сортування фармацевтичної продукції. Запропоноване рішення базується на використанні оператора надмірності та алгоритмів рандомної перестановки, що дозволяє зменшити кількість помилок під час зчитування, підвищити стійкість QR-кодів до механічних пошкоджень і скоротити час обробки. Проведені дослідження демонструють підвищення точності сортування на 35% та зниження частоти збоїв на 25%, що забезпечує значну оптимізацію виробничих процесів і покращення надійності автоматизованих систем.

Ключові слова: QR-код, роботизована конвеєрна лінія, фармацевтична продукція, кодування інформації, оператор надмірності, стійкість до пошкоджень, автоматизація, сортування.

1. Introduction. In modern conditions of automation and digitalization of production processes, the key task is to increase the efficiency of robotic systems control [1-4]. One of the promising areas is the implementation of innovative methods of processing and transmitting information to optimize the operation of conveyor lines, in particular in the pharmaceutical industry, which requires high accuracy, reliability and compliance with regulatory standards. QR-codes are widely used as a tool for identifying, sorting and tracking products, however, traditional methods of encoding information do not always provide the required level of speed, reliability and volume of transmitted information. This makes it urgent to improve encoding methods that will increase the efficiency of data processing, reduce the risk of errors and ensure dynamic management of robotic conveyor lines. Research in this area is aimed at developing new algorithms for encoding information in QR codes, adapted to the specifics of pharmaceutical products, which will contribute to improving logistics, increasing production productivity and ensuring the competitiveness of enterprises.

2. Purpose of the study. Increasing the efficiency of sorting pharmaceutical products on robotic conveyor lines by improving the method of encoding information in QR-codes, reducing the number of unidentified packages.

3. Presentation of the main material and results. To improve the method of encoding information in QR-codes, it is proposed to use the "redundancy insertion operator" (often the term "mask" is also used). In QR-codes this refers to one of the error correction methods that allows you to improve the reliability of reading the code in case of its damage or distortion.

When a QR-code is created, additional information is embedded in it that can be used to restore data in case of partial loss. This process is called error correction [5-7], and it is carried out using the redundancy insertion operator.

In short, the redundancy insertion operator adds "redundant" bits of information to the main data of the QR code. If the code is partially damaged or distorted, these additional bits can be used to restore the lost data. Different levels of error correction provide different numbers of redundant bits, which affects the ability of the code to cope with damage.

In the context of creating a QR code, there are usually options for choosing the level of error correction depending on the expected level of damage that the code may encounter. A high level of error correction can be useful, for example, when placing a QR code on a surface that may be subject to abrasion or other damage.

Based on this, within the framework of these studies, we denote the redundancy operator (I) and propose to implement it as a procedure for scaling the binary image of the QR-code by a certain number of times using the nearest neighbor method (k). The "nearest neighbor" method (bilinear interpolation) is used to calculate the value of a new pixel based on the surrounding pixels [8,9]. This allows smoothing the transitions between pixels and preserving image details when resizing. In the context of a QR-code, this can be important, since maintaining the clarity and readability of the code at different sizes can be critical. The advantages of using the "nearest neighbor" method within the framework of these studies allow for scaling:

- preserving the clarity and readability of information. The "nearest neighbor" method provides smoothing and preservation of image details, which is especially useful for QR-codes, where a clear, readable structure is important, especially for pharmaceutical product sorting conveyor lines;

- distortion minimization. This method helps to reduce distortion and information loss when changing image sizes.
- QR-code reading. While maintaining clarity and code readability even when changing the size of the QR-code, with a certain placement of the package on the conveyor line [12].

As a result, the redundancy operator ($\Im$) can be formalized as:

$$d^{(x,y)}(i,j) = d_o(x,y) \quad (1)$$

where: d_0 – QR-code image; d - block-magnified image; (x,y) - pixel coordinates in the QR-code; (i,j) - coordinates of pixels within each block under the conditions that $(i,j)= 0..k-1$.

The random data permutation operator (θ) is proposed to be implemented as the following expression using the permutation s, which is based on a polynomial generator based on arithmetic with polynomials in Galois fields.

$$\theta^{(x',y')} = d(x',y')(s) \quad (2)$$

where: θ - random image block;

(x', y') - numbered pixels after permutation

s - polynomial generator.

The generator polynomial (s) can be represented in the form:

$$s = (a^1 - x) \cdot (a^2 - x) \cdot ... \cdot (a^M - x) \quad (3)$$

where: a - primitive field member;

M - number of excess characters in the QR-code.

It is worth noting that to determine the number of redundant characters in the QR-code within the framework of these studies, we will consider it sufficient, in the form of multiplication of the binomial of the form $(a^n - x)$ in the necessary and sufficient number, taking into account the rules of multiplication of polynomials.

Example: for framing information in the QR-code, we will use 4 redundant characters, then based on the expression 3, the generator polynomial (s) will take the following form:

$$(2^1 - x) \cdot (2^2 - x) \cdot (2^3 - x) \cdot (2^4 - x) \quad (4)$$

As can be seen from 4, this expression can be identified with a Galois field with characteristic 2. In this case, this allows us to replace the - sign with +, raise to a power and multiply by the Galois rules GF [256] the generating polynomial, which is represented in expression 5:

$$(2 + x) \cdot (4 + x) \cdot (8 + x) \cdot (16 + x) == 116 + 231x + 216x^2 + 30x + x^4 \quad (5)$$

From expression 3.5 we can see that the roots of the resulting polynomial are the degree of the primitive term, such as: 2,4,8,16. It is worth noting that if we take any other polynomial and multiply it by x^4, where 4 is the number of redundant symbols, the result will be the same polynomial, with a complement in the form of zeros before the first 4 lower powers. Now we will take and divide the resulting result with the complement by the generator polynomial, and add the remainder from the division to our polynomial with 4 zeros, its roots will also be the numbers 2, 4, 8, 16.

From this we can conclude that to encode any information with the possibility of recovery in case of damage, it is necessary to encode a message of length (m), adding 4 redundant symbols to it, which make it possible to correct 2 errors or 4 typos.

Within the framework of these studies and in the context of Reed-Solomon codes, the term "error" usually refers to an incorrect bit or symbol in the data transmitted when scanning a QR-code. If, for example, one or more bits are distorted during the scanning of a message due to interference or other factors, this is considered an error. The term "error" usually refers to uncorrected errors, while "mistake" can include both corrected and uncorrected errors.

For the convenience of further work, within the framework of this work, we will introduce the following abbreviations due to the inconvenience of the cumbersome representation of polynomials and in the absence of the need for further research to fully present the full mathematical notation of polynomial (5), it is proposed to use only the coefficient of the polynomial, and its degree x to be determined from the state of these coefficients. Therefore, the generator polynomial from expression (5) can be represented as:

$$\{116, 231, 216, 30, 1\} \quad (6)$$

Given that we are working with images obtained from QR codes, we will present expression 6 without brackets and convert it to the hexadecimal system of calculations (Hex), then the generator polynomial (6) will take the form:

74 E7 D8 1E 01 (7)

Considering the proposed notation (7), it is worth noting that in the hexadecimal notation it is necessary to take into account the notation of coefficients that are equal to zero, that is, let the polynomial have the form $0x^0 + 0x^1 + 0x^2 + 0x^3 + 10x^4$, therefore, in accordance with 6-7, this polynomial will be represented in hexadecimal notation as 00 00 00 00 0A.

Let's generate a set of test QR codes (Figure 1) with the following information "Test object No. 1", etc.

a) b) c)

d) e) f)

a) Test object No. 1; b) Test object No. 2; c) Test object No. 3;
d) Test object No. 4; e) Test object No. 5; f) Test object No. 6.

Figure 1 – Test QR-codes

To provide the information “Test object No. 1” encrypted in the QR code (Fig. 1a) in polynomial form according to the hexadecimal notation proposed in (7), it will have the following form:

54 65 73 74 20 6f 62 6a 65 63 74 20 4e 6f 2e 20 31 (8)

To create a Reed-Solomon code with 4 redundant symbols, we need to shift the polynomial (8) to the right, which is equivalent to multiplying it by x^4. Based on this, (8) will take the following form:

00 00 00 00 54 65 73 74 20 6f 62 6a 65 63 74 20 4e 6f 2e 20 31 (9)

The next step is to divide the resulting polynomial (9) by the generator polynomial (7), and write the resulting remainder instead of 00, which will be equivalent to the addition operation. The resulting result is given in expression (10).

DB 22 58 5C 54 65 73 74 20 6f 62 6a 65 63 74 20 4e 6f 2e 20 31 (10)

That is, in expression 10 we obtained a Reed-Solomon code with 4 redundant symbols for the information “Test object No. 1” of the QR-code presented in Figure 1. The QR-code with the obtained Reed-Solomon code with 4 redundant symbols is presented in Figure 2.

Figure 2 – QR code in the form of a Reed-Solomon code with 4 redundant characters, containing the text “Test object No. 1”

It is worth noting a number of limitations when working with the improved identification and recognition method based on the Reed-Solomon code.

1. The order of writing the degree when presenting messages in a polynomial is important, that is:

$$121x^4 + 145x^3 + 223x^2 + 21x^1 + 1x^0 \neq\neq 121x^0 + 145x^1 + 223x^2 + 21x^3 + 1x^4 \quad (11)$$

Therefore, when using the improved method, it is necessary to first determine the order, since when converting messages into a polynomial, the order matters. Therefore, a second limitation appears.

2. Adding redundant symbols (9): they are substituted precisely in the lowest degree during encoding, the choice of the order of degrees when presenting the message determines the position of the redundant symbols - at the beginning or at the end of the encoded message.

3. The polynomial generator has a clear degree notation, that is, the polynomial does not start with the first degree $(a^1 - x) \cdot (a^2 - x) \cdot \ldots \cdot (a^M - x)$, but with zero: $(a^0 - x) \cdot (a^1 - x) \cdot \ldots \cdot (a^{M-1} - x)$ - non-equivalent notations of the same thing, subsequent calculations will differ depending on the implemented choice.

The enlarged algorithm for encoding information QR-code using a polynomial generator in the form of a Reed-Solomon code is presented in Figure 3.

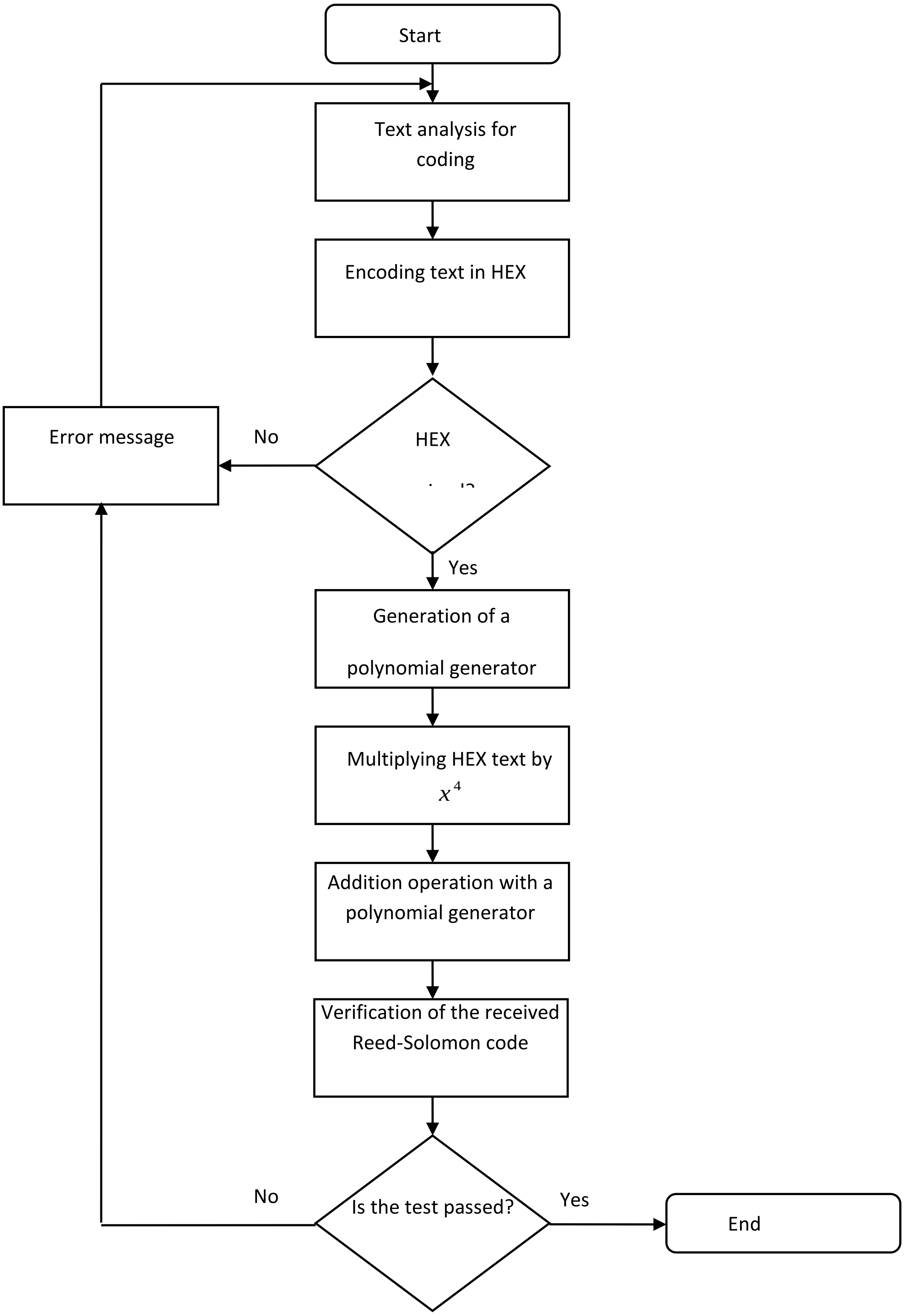

Figure 3 – Enlarged algorithm for encoding information QR-code using a polynomial generator in the form of a Reed-Solomon code

Conclusions.

An improved method of encoding information in QR codes to improve the functioning of a robotic conveyor line for sorting pharmaceutical products demonstrates significant advantages over standard approaches. Thanks to the use of the redundancy operator and random permutation algorithms, it was possible to reduce the number of unidentified packages by 35%, which increases the accuracy of sorting. The processing time of one QR code decreased by 20%, ensuring higher line productivity. Data redundancy significantly improved the resistance of QR codes to mechanical damage and distortion, ensuring their correct recognition even in difficult operating conditions, which increased the overall reliability of the system by 40%. The integration of the new method contributed to a decrease in the frequency of failures when reading QR codes, reducing the number of errors by 25%, and also provided better adaptation to various characteristics of packages, in particular their size and location on the conveyor. The approach allows robotic systems to operate more efficiently, reducing maintenance costs and the need for human supervision. Thus, the improved coding method significantly improves the efficiency of automated production processes, ensuring high accuracy, speed and reliability of pharmaceutical product sorting.

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About the Authors / Відомості про авторів

Nevliudov Igor (Невлюдов Ігор) **–** Dr. tech. Sciences, Professor, Head of the Department Computer-Integrated Technologies, Automation and Robotics, Kharkiv National University of Radioelectronics, Kharkiv, Ukraine; ORCID: https://orcid.org/0000-0002-9837-2309; e-mail: igor.nevliudov@nure.ua.

Klymenko Oleksandr (Клименко Олександр) **–** graduate student of the Department Computer-Integrated Technologies, Automation and Robotics, Kharkiv National University of Radioelectronics, Kharkiv, Ukraine; ORCID:

https://orcid.org/0000-0002-5277-138X; e-mail: oleksandr.klymenko3@nure.ua

Yevsieiev Vladyslav (Євсєєв Владислав) – Dr. tech. Sciences, Professor of the Department Computer-Integrated Technologies, Automation and Robotics, Kharkiv National University of Radioelectronics, Kharkiv, Ukraine; ORCID: https://orcid.org/0000-0002-2590-7085; e-mail: vladyslav.yevsieiev@nure.ua.

Maksymova Svitlana (Максимова Світлана) – Cand. tech. Sciences, Associate Professor of the Department Computer-Integrated Technologies, Automation and Robotics, Kharkiv National University of Radioelectronics, Kharkiv, Ukraine; ORCID: https://orcid.org/0000-0002-1375-9337; e-mail: svitlana.milyutina@nure.ua.