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UDK: 003.295.8 **Research paper**

Automatic identification based on 2D barcodes

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Abstract

Identification of products by using barcodes has been researched for decades and is broadely applied in practice. Today there is almost no consumer product without a barcode. With the introduction of 2D barcodes (2D codes), the capacity to encode data has dramatically increased, and consequently the possibility of storing more data in the code itself. Greater capacity for storing data in a 2D code opens new possibilities, such as transfer of basic information about a product, like the instructions for use, method of transportation, etc., without the need for pairing data from the barcode with a database where further informations are stored, as is the case with the conventional linear barcodes. On the other hand, the recognition of 2D codes is more hardware and software demanding. In this paper, the most common types of 2D barcodes are described, and it is specified how these codes are encoded and decoded, what is their data capacity and posibility of application. Furthermore, an application for automatic identification based on 2D barcodes is realized in Matlab, which uses an IP camera for image acquisition, processes it and reads the available barcode, and reproduces the read text through generated speech.

Key words: *Automatic identification, barcode, 2D code, QR code, Data Matrix*

1. INTRODUCTION

Product identification by using linear barcodes has been present on the market for more than five decades. Today there is no product without a designated barcode, regardless of its quality or value. Printing barcode on the product does not require additional cost, and investment in hardware required for its reading is negligible compared to the simplification of product identification.

With the appearance of 2D barcode (2D code) for encoding data, the capacity has dramatically increased, and therefore the possibility of recording more data in the code. The ability to transfer large amounts of data gives room for the transmission of additional information, such as information about the product, instructions for use, way of transportation, etc. This information can be entered in the 2D code itself, and users can read the required data without connecting to a database where this information would be stored. Another option is to code only the website address (server) where the adequate data is located. For example, in Japan, McDonald's hamburgers have a QR code on their package, and by scanning it, the user gets the address of the web site which contains all the nutritional values of the product. Another example is in postal services, where information from the barcode (mostly 1D codes intended for postal traffic or data matrix code) contains the adequate code for the post (which is used for recording and monitoring), type of the post, country, price, etc.

Compared to linear barcode, identification of 2D code is more demanding, since there are multiple types and

subtypes of this code, and the decoding is done in multiple dimensions. Decoding of 2D barcode requires better optics, higher processing power, more complex algorithms, and different way of data representation.
The following chapters describe the types of two-dimensional barcodes, their characteristics, data capacity, as well as protection levels for error correction for errors causes by physical damage of the printed barcode or by inadequate code reading. Finally, this paper's goal is to present some of the possibilities of 2D codes applications for automatic identification.

2. BARCODE TYPES

A barcode is an optical machine-readable representation of data, which shows data about the object to which it attaches. Linear (1D) barcodes represented data by varying the widths and spacing of parallel lines. Later they evolved into rectangles, dots, hexagons and other geometric patterns in 2 dimensions (2D) – matrix code. Although 2D systems use a variety of symbols, they are generally referred to as barcodes as well. [1]
The first use of barcodes was to label railroad cars, but they were not commercially successful until they were used to automate supermarket checkout systems, a task for which they have become almost universal. Their use has spread to many other tasks that are generically referred to as automatic identification and data capture (AIDC). The very first scanning of the now ubiquitous Universal Product Code (UPC) barcode was on a pack of Wrigley Company chewing gum in June 1974 [1].
Other systems have made inroads in the AIDC market, but the simplicity, universality and low cost of barcodes has limited the role of these other systems until the first decade of the 21st century, over 40 years after the introduction of the commercial barcode, with the start of commercial use of technologies such as radio frequency identification (RFID).
Two-dimensional codes offer possibilities for applications where a greater data capacity is required than the capacity of a linear barcode, and are advantageous to other forms of identification for their low price. At the moment there are roughly 50 globally applied types of 2D codes, but the Data Matrix and QR code are mostly used in common applications (Fig. 1).

Figure 1. Data Matrix (left) and QR code (right) with coded text: IS'11 Automatic identification based on 2D barcodes

2.1 **QR code**

QR Code (quick response) is a two-dimensional barcode defined by the ISO/IEC18004 industrial standard, designed and protected by the Japanese company Denso Wave Incorporated, developed with a main objective of "Code read easily for the reader" in 1994.
The QR code carries meaningful information in the vertical direction as well as the horizontal, hence the two-dimensional term. By carrying information in both directions, QR code can carry up to several hundred times the amount of data carried by ordinary bar codes [2].
QR code enables encoding of the following types of input data:

- Numbers: digits 0-9 (expressed in bits 30HEX-39HEX);
- Alphanumerical data:
  - o digits 0-9 (30HEX-39HEX),
  - o capital letters A-Z (41HEX-5AHEX),
  - o special signs: space % $ * + - . , / : (
- Binary data (defined by ISO/IEC 8859-1 standard): each byte sign is coded with 8 bits;
- Kanji (a format that supports representation of Chinese signs).

Basic characteristics of the QR code are presented in Table 1.

Table 1. QR Code Outline Specification [2]

Symbol size	21×21 - 177×177 modules (size grows by 4 modules/side)	
Type & Amount of Data (Mixed use is possible.)	Numeric	Max. 7,089 characters
	Alphanumeric	Max. 4,296 characters
	8-bit bytes (binary)	Max. 2,953 characters
	Kanji	Max. 1,817 characters
Error correction (data restoration)	Level L	Approx. 7% of codewords can be restored.
	Level M	Approx. 15% of codewords can be restored.
	Level Q	Approx. 25% of codewords can be restored.
	Level H	Approx. 30% of codewords can be restored.
Structured append	Max. 16 symbols (printing in a narrow area etc.)	

The large data capacity (over 4000 alphanumeric characters) puts the QR code among the codes that can be used for storing the required information about the product itself, its ways of transport and storage, and its final disposal at the end of life cycle.
Each QR code symbol (Fig. 2) is structured with dark (logical one) and light (logical zero) square modules, arranged evenly in a grid of adequate size. The minimum size of each module should be 4x4 pixels at a resolution of 300 dpi printing. Each symbol consists of functional patterns and coding patterns. Functional patterns do not contain encoded data.

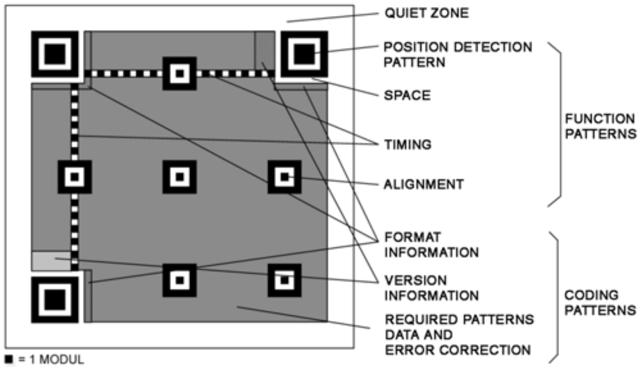

Figure 2. QR code structure scheme

- *Position detection pattern:*
  - o 3 equal position patterns in each symbol.
  - o each position pattern consists of three concentrical squares, with the side lengths of 7, 5 and 3 modules, i.e. the width ratio of different parts is 1:1:3:1:1 as illustrated on Fig. 3.
  - o the position pattern is constructed so that there is very little possibility that a similar shape appears in the space of encoded data. Detection of the three position patterns completely determines the position and orientation of the QR code.

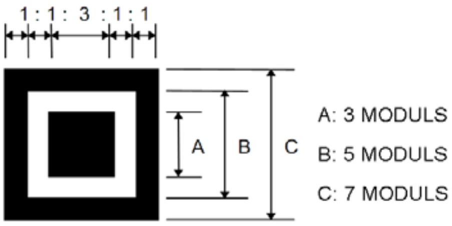

Figure 3. Position pattern

- *Space:* between each position pattern and the rest of the symbol, there is a space one module wide.
- *Timing pattern:* there is one horizontal and one vertical alternating pattern.
  - o are one module wide,
  - o specify the density and the version of the symbol,
  - o represent coordinate axes for determination of position of each module in the symbol.
- *Alignment patterns*:
  - o each pattern is composed of concentrical squares with side lengths of 5, 3 and 1 module,
  - o number of these patterns is dependent on the applied type of QR code.
- *Quiet zone*: space around the symbol, 4 modules wide, with equal visual reflection as the light symbol modules.
- *Data and error correction patterns*:
  - o patterns for data coding
  - o patterns for error correction coding

There are 40 versions of QR codes. Version 1 consists of a square of 21x21 modules size (Fig. 4), and every following version is 4 modules larger on each side. The largest version is version 40 which consists of a square of 177x177 modules size.

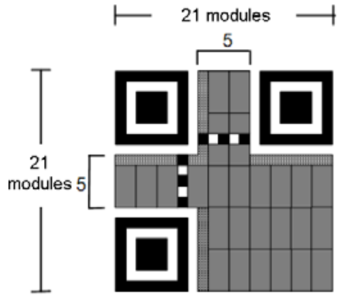

Figure 4. QR code, version 1

QR Code implements the Reed-Solomon algorithm to generate the data codewords and error correction codewords [3]. Errors in the code can occur while reading the coded image, due to damage of the image itself or due to non-compliance of the reader's resolution and image size, due to the image distortion caused by the angle of image shooting, light reflections in the image etc. There are four levels of error protection, which are selected by the user during the code generation (Table 1).

The data is encoded according to the chosen symbol type, and the resulting bit arrays are devided in segments of 8-bit codewords. Redundant codewords are added to fill the remaining empty places for codewords for the given symbol size. The bits are arranged in blocks of 2x4 size, which can be regular – vertical or horisontal (Fig. 5.a, b and d), and irregular – used when block orientation is changing or when the block position is next to the functional pattern (Fig. 5.c and e).

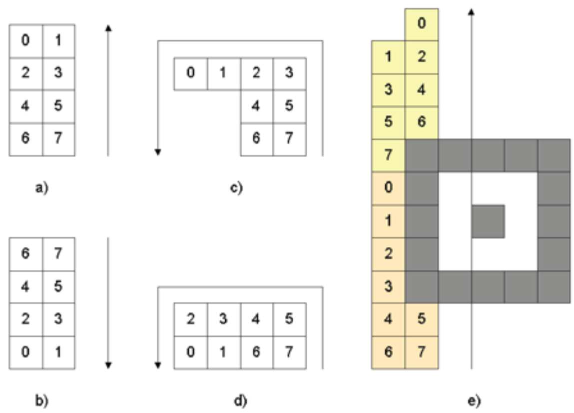

Figure 5. Possible orientations and positions of blocks of codewords

Aligning the blocks (Fig. 6) in a symbol start in the bottom right corner of the symbol, with a starting vertical alignment direction, and then to the left. The most significant bit (bit 7 in Fig. 5) of the codeword in a block always takes the first free place in the block.

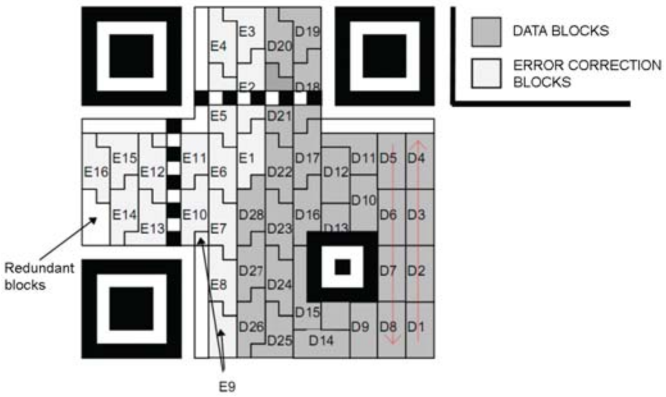

Figure 6. Data and EC blocks position in a QR code

2.2 **Data Matrix code**

Data Matrix is a matrix (2D) barcode which may be printed as a square or rectangular symbol made up of individual dots or squares. This representation is an ordered grid of dark and light modules (pixels) bordered by a finder pattern. The finder pattern is partly used to specify the orientation and structure of the symbol. The data is encoded using a series of dark or light dots based upon a pre-determined size. [4]

A Data Matrix symbol is composed of two separate parts (Fig. 7): the finder pattern, which is used by the scanner to locate the symbol, and the encoded data itself. The finder pattern defines the shape (square or rectangle) and the size of the symbol, and allows the scanner to identify the symbol as a Data Matrix.

The finder pattern consists of two parts:

- *"L finder pattern"* – It consists of two dark lines, on the left and bottom of the symbol, and is primarily used to determine the size, orientation and distortion of the symbol.
- *"Clock Track"* – Alternating light and dark elements on the other two sides of the finder pattern. This defines the basic structure of the symbol and can also help determine its size and distortion.
-

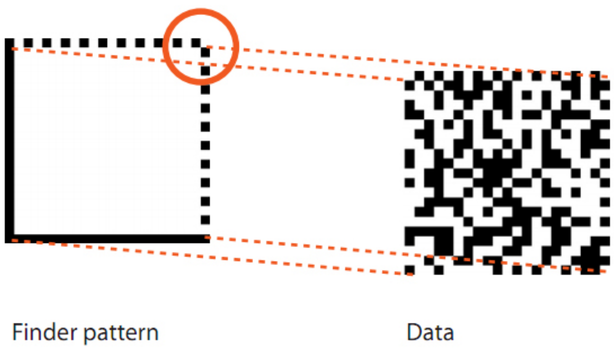

Figure 7. Data Matrix code structure

The data is encoded in a matrix within the Finder pattern. This is a translation into the binary Data Matrix symbology characters (numeric or alphanumeric).

Data Matrix has a mandatory Quiet Zone. This is a light area around the symbol which must not contain any graphic element that may disrupt reading the bar code.

The newest version of Data Matrix is ECC200, and today it is mostly used for common applications. Symbols have an even number of rows and an even number of columns. Most of the symbols are square with sizes from 10×10 to 144×144, but the standard also allows rectangular symbols with sizes from 8×18 to 16×48. All symbols utilizing the ECC200 error correction can be recognized by the upper right corner module being the same as the background color (binary 0).

The ECC200 supports advanced encoding error checking and correction algorithms, e.g. the Reed-Solomon method. ECC200 allows reconstruction of the data, even when the symbol is 30% damaged. Data Matrix has an error rate of less than 1 in 10 million characters scanned.

The amount of data that can be encoded in a Data Matrix symbol is at most:

- 2,335 alphanumeric characters
- 3,116 numbers

in a symbol made up of 144 rows and 144 columns. However, for the Data Matrix in the rectangle-form, the maximum capacity is:

- 72 alphanumeric characters
- 98 numbers.

For symbols sizes from 8x8 to 26x26 pixels, the symbol contains only one data region. For larger sizes, the symbol is divided into four smaller data regions, and with even greater sizes, into more small data regions. The largest symbol of 144x144 pixels is divided into 36 smaller data regions.

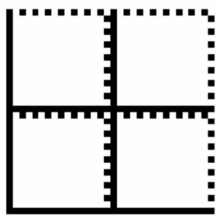

Figure 8. An example of a finder pattern for a symbol divided into four data regions

Each symbol character is represented by eight modules (pixels) which are square shaped, and each module represents a binary bit. The eight modules are in order from left to right and top to bottom, to form a symbol character (Fig. 9). As this symbol character shape cannot be perfectly nested at the symbol boundary, some symbol characters are split into portions on the opposite sides of the symbol (Fig. 10). [5]

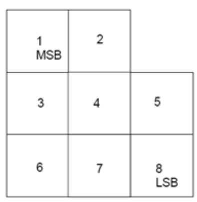

Figure 9. The shape of a data character in a Data Matrix symbol, MSB – most significant bit, LSB – least significant bit

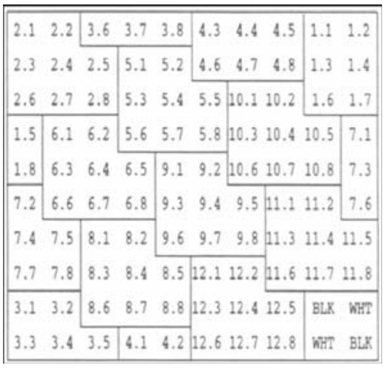

Figure 10. An example of a 10x10 ECC200 Data Matrix symbol, with the adequate character positions

3. ANALYSIS OF 1D AND 2D BARCODE APPLICATION POSSIBILITIES

Linear barcodes are primarily used for product identification, while the application of RFID tags [6,7] or two-dimensional bar codes allows the possibility of storing additional product data on the tag or the code itself, and not just the basic data for the product (object) identification. In the recent years, RFID technology has been increasingly used for automatic identification of products. RFID has its advantages (the ability of rapid data reading: eg. at the cashiers in mega-markets) and its disadvantages (mainly the cost of the tag, compared to the bar code which is free). On the other hand, barcode has been used for automatic identification for more than five decades. Compared to linear barcodes, 2D codes have a greater capacity, as shown in Table 2, where the maximum amount of data that can be encoded with a certian code type is shown.

Table 2. Comparison of data capacities for different code types

	1D Bar code	Type	QR code (177x177)	Data matrix (144x144)
Numeric	12	UPC	7089	3116
Alpha numeric	each character use 6 pixels + start and stop bits	Code-128	4296	2335
Binary (8bit)	-		2953	1555
Kanji	-		1817	-

Table 2 shows that in the case of a linear barcode of type Code-128 there is no limit in the number of characters, as the code width is increased with 6 line widths per each additional character, but it is obvious that only a limited number of characters can be used in realistic situations, as the overall width should not exceed the width of 10-15 characters to obtain a reasonably readable code.

In the case of two-dimensional barcodes, QR code is preferred, as it has around 33% higher capacity for storing alphanumerical signs and the code structure provides much higher readability than the Data matrix.

Automatic identification of products, that has been used for decades with the application of linear barcodes (mostly UPC and Code-128), could be enhanced with the application of QR code or Data matrix, which would provide the possibility of storing additional product data. This data could improve and facilitate the transport, storage, usage and disposal of products at the end of their life cycle.

The appearance of smart phones with cameras of adequate resolution and a powerful processor has enabled many users to detect and decode the data contained in a barcode. This fact brought up the idea of storing important data about the product, such as usage instructions, various warnings (e.g. contraindications for using a certain medicine, information about possible allergic reactions for a food product, etc.), storage instructions, product expiration date, etc, which could be stored in 2D codes as they offer higher capacity. Each user could easily read this data by a dedicated application on their mobile phone.

In order to research the possibilities for decoding and representing the encoded content in 1D and 2D barcodes, a dedicated program has been realized in Matlab. This program uses an IP camera to acquire an image containing a barcode, detects the code in the image and decodes the contained text. The decoded text is shown on the computer monitor and reproduced through the speakers (Fig. 11).

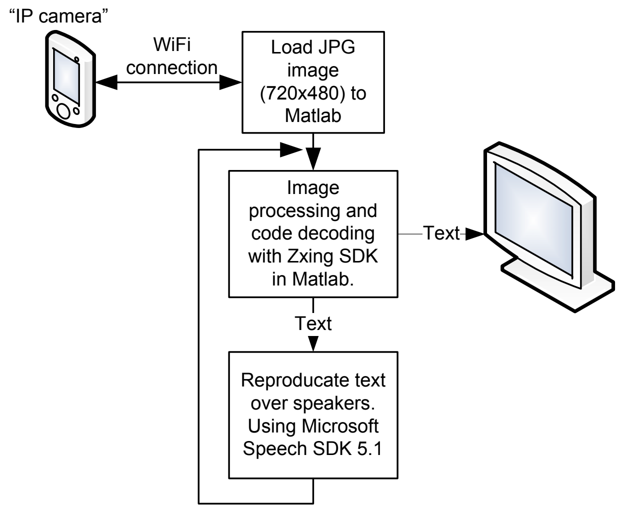

Figure 11. Simplified block diagram for operation mode of the program for decoding barcode data

An image 720 pixels wide and 480 pixels high is imported to the Matlab environment from the IP camera (Fig. 12). As an IP camera, a mobile phone HTC Desire has been used, with an installed software for simulating the IP camera through a Wi-Fi connection. The acquired image is analysed by using the ZXing ("zebra crossing") open-source, multi-format 1D/2D barcode image processing library implemented in Java (http://code.google.com/p/zxing/). This software development kit (SDK) is focusing on analysis of images containing various barcode types and decoding the encoded data from the barcode. The SDK currently has support for:

- UPC-A and UPC-E (Universal Product Code)
- EAN-8 and EAN-13 (originally European Article Number, but now renamed International Article Number even though the abbreviation EAN has been retained)
- Code 39
- Code 93
- Code 128
- QR Code
- ITF
- Codabar
- RSS-14 (all variants)
- Data Matrix
- PDF 417 ('alpha' quality)
- Aztec ('alpha' quality)

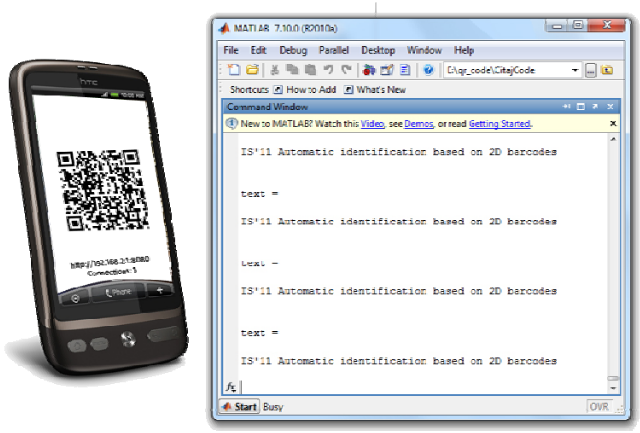

Figure 12. Bar code recognition program in Matlab

The image acquired from the camera is first converted to a black and white image, where a search is performed for locating an object that could be a barcode. If such an object is located, the image is corrected (distortion correction, image scaling) and the adequate code type is detected. If the code is valid, it is decoded to the adequate text output as a string of characters. If the code is unreadable, or non-existent in the image, the output is an empty string. After displaying the decoded text on the computer screen, the text is reproduced on the speakers with the use of the Microsoft Speech SDK 5.1.

This SDK is primarily intended for generating English words, which are generally well generated and pronounced, but for other languages it is not yet adequate. This SDK enables speech speed and speaker voice adjustment.

4. CONCLUSION

Automatic identification of products, objects and users has been performed by using barcodes, RFID tags, magnetic stripe cards, smart cards, etc. As the price of using barcodes is still the lowest, possibilities of using barcodes in product identification have been analysed in this paper.

This paper presents the main differences between linear (1D) and 2D barcodes. The structure of two most present codes was described: QR code and Data matrix. Also, a comparison has been given that shows the difference in maximum data capacities of 1D barcodes (UPC and Code-128) and 2D barcodes (QR code and Data matrix).

Using the 2D barcodes allows the possibility for including additional information about the product, which can be read by the user's reading device. A great number of users possesses a newer generation smart phone with and adequate camera and a fast processor, which enable reading of various barcodes. This fact allows the possibility for storing additional data about the product in the barcode itself.

This paper shows a solution realized in Matlab environment for reading and decoding barcodes based on an opensource SDK Zxing. This SDK allows detection and decoding of more than ten different types of 1D and 2D barcodes. The program in Matlab also allows reproduction of the decoded content through the computer speakers, which would help people with sight or reading dificulties to read the required product data. For speech generation, the Microsoft Speech SDK 5.1 has been used, where the text gained from the barcode is interpreted in the adequate way, and sent to the speakers as output. The major drawback of using this SDK is that it is intended for english speech generation, and it does not have an adequate support for other languages.

The research presented in this paper wil be followed with further development of the application for portable devices (PDA, other mobile phones). Except textual representation of the acquired data, the application should enable various ways of representing the required information, such as speech, transfer over Wi-Fi, Bluetooth, IRDA, etc.

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Automatska identifikacija zasnovana na 2D bar-kodovima

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Rezime

Identifikacija proizvoda pomoću bar-kodova istražuje se decenijama i u velikoj meri se primenjuje u praksi. Danas gotovo da ne postoji potrošački proizvod bez bar-koda. Sa uvođenjem 2D bar-kodova (2D kodova), kapacitet za kodiranje podataka se drastično povećao, a sa njim i mogućnost za skladištenjem više podataka u samom kodu. Veći kapacitet za čuvanje informacija u 2D kodu otvara nove mogućnosti, poput prenosa osnovnih informacija o proizvodu, kao što je uputstvo za upotrebu, način transporta, i sl., bez potrebe za povezivanjem podataka sa bar-koda sa bazom podataka gde se nalazi više informacija, kao što je slučaj sa konvencionalnim linearnim bar-kodovima. Sa druge strane, prepoznavanje 2D kodova zahteva bolju opremljenost hardvera i softvera. U ovom radu opisani su najčešći tipovi 2D bar-kodova, i posebno je istraknuto kako se ovi kodovi kodiraju i dekodiraju, koji je njihov kapacitet čuvanja podataka i mogućnost primene. Nadalje, primena automatske identifikacije zasnovane na 2D bar-kodovima je realizovana u Matlabu, gde se koristi IP kamera za prikupljanje slika, njihovu obradu i čitanje dostupnog bar-koda, kao i reprodukciju čitanog teksta putem generisanog govora.

Ključne reči: *automatska identifikacija, bar-kod, 2D kod, QR kod, Data Matrix*