2D-Codes

Technology and Application

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1 Introduction

Increasing customer expectations and cost pressure intensify the competition in many businesses. New technologies can help to gain competitive advantages and reduce cost at the same time. The integration of the real world into the digital one will be key to enable automated processes. The increasing distribution of modern handhelds, with high-resolution displays and cameras, favors 2D-Codes as an innovative and cost-efficient solution for customer integration and the linkage of both worlds. After a short technology overview and description of common 2D-Codes, the article introduces several usage scenarios. In certain businesses, for example ticketing, 2D-Codes are already established and have proven the potential and road capability. Finally, the paper ends with an outlook about the future development of 2D-Codes and the advantages over RFID technology (Lammert and Grauer 2006, pp. 198–205).

2 Technology

In the following section, the 2D-Code technology is described as an evolution of the one-dimensional barcode technology. 1D-barcodes, e.g., the European Article Number (EAN) Codes, consist of several bars of different width which are arranged in a parallel way and are separated from each other by gaps. The crucial characteristic of these codes is that the information which they contain can be read by barcode scanners and can be processed automatically by IT-systems.

2.1 What is a 2D-Code

The first 2D-Codes, like the PDF417 by Symbol Technologies, were developed in the late eighties (Renn 2004). Nowadays, approximately 70 different types of 2D-Codes exist which differ in regards to their structure, their storage capacity, and particularly their application area. An overview and a description of the most popular 2D-Codes are provided by Adams (2009) and the **Table 1**. 2D-Codes have a two-dimensional structure and therefore can, in contrast to 1D-Codes, encode information not only horizontally but also vertically. This means that data can be stored in a two-dimensional space. The resulting advantages are an increased storage capacity, a higher error tolerance, and extended storage possibilities.

Storage capacity: Being able to store information in a two-dimensional space, there is a relatively small need for space per character which increases the storage capacity of the code significantly. A one-dimensional EAN-13 code, for instance, can store only 13 characters at maximum. A two-dimensional Quick Response (QR) code, however, can encode up to 7089 characters. Put differently, a QR-Code requires only a tenth of the space for storing the same amount of data as an EAN-Code (n.a. 2010).

Error tolerance: 2D-Codes exhibit a high tolerance in regards to pollution, low-quality printouts, or damage because a code contains the same information up to four times redundantly. By using the Reed-Solomon error correction technique (Wicker and Bhargava 1994), even heavily damaged codes can still be read correctly. The error correction process is executed according to the error correction level that has been set by the user. The level should be set in correspondence to the size of the code and the extent of damage.

Extended storage possibilities: Another advantage which 2D-Codes hold over 1D-Codes is that not only numeric but almost any kind of information, such as text, URLs, and addresses, can be encoded by them. Apparently, a growing information density also requires the size of the code to grow. A 2D-Code which encodes a telephone number, for instance, is considerably smaller than a code which stores a complete address.

2.2 What Is the Structure of a 2D-Code and How Can It Be Scanned?

Describing the structure of 2D-Codes, stapled and matrix codes need to be distinguished. *Stapled codes*, like the PDF417, consist of several one-dimensional barcodes which are stapled on top of each other. The data is arranged in various stapled rows which are read from the left to the right and from the top to the bottom. Quiet zones are located at the start and at the end of each row. These zones are needed by the scanner in order to identify the surface which is intended to be encoded. Through start and stop patterns the code signals to the scanner where it should start or stop reading. The indicators define the left

Table 1 Overview of 2D-Codes

Overview of 2D-Codes					
		QR code	PDF417	Aztec	DataMatrix
Type		Matrix	Stapled barcode	Matrix	Matrix
Capacity:	Numeric	7089	2710	3832	3116
	Alpha-numeric	4296	1850	3067	2355
	Binary	2953	1018	1914	1556
Main characteristics		3 position markers, easy to scan, large capacity	Ideal for print-outs	1 position marker, applicable for all kinds of displays	Very small print-outs are possible
Application areas		Marketing, Mobile Tagging	Paper-based tickets and boarding passes	Electronic tickets and boarding passes	Logistics and production (marking very small elements)

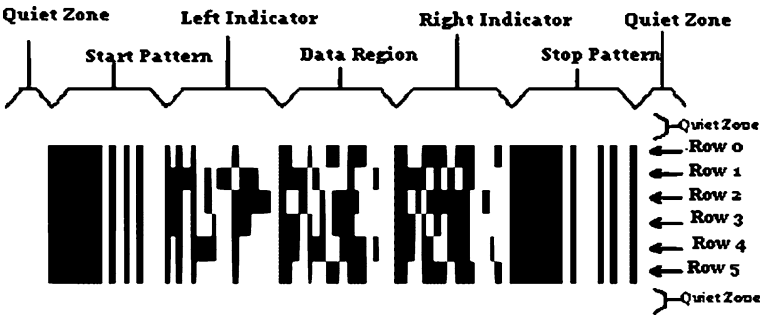

Fig. 1 PDF417-Code (n.a. 2010)

and the right of the code which is important because the scanner could be placed on the code from various angles. **Figure 1** shows the structure of a stapled code using the example of a PDF417.

Matrix-codes, sometimes called *array-codes*, store the data both horizontally and vertically. Typical examples for array-codes are the QR- and the Aztec-Code. Three position markers define the direction a QR-Code has to be read from. The scanner starts reading from the corner where no position marker is located. Additionally, the version, the format, and the key for the error correction are recorded in the code. The structure of an Aztec-Code is different from the one of a QR-Code because the position marker is located in the center of the code. The scanning direction is from the inside to the outside and each data-layer is completely encompassed by the preceding one. **Figure 2** shows an example of an Aztec-Code and **Fig. 3** shows one of a QR-Code. Both codes encode the URL http://www.unisg.ch/.

Fig. 2 Aztec-Code (RACO Industries 2010)

Fig. 3 QR-Code (Kaywa 2010)

2D-Codes cannot be read by existing barcode scanners, like Laser- or Charge Coupled Device (CDD) scanners. Instead, so-called Imagers (camera scanners) have to be deployed. First, the code is captured by the imager, then it is decoded using digital image processing and finally the stored information is displayed (e.g., a website, text, or an address). Thereby, the code can either contain the information itself or it contains the reference to an external server where the actual information is stored. If a mobile phone has an integrated digital camera and the appropriate scanning software, it can also be used to read 2D-Codes.

3 Application Areas

In the following section, some of the most popular application areas of the 2D-Code technology are described. The key finding is that certain types of codes are particularly appropriate for certain ap-

plication areas because of their specific characteristics.

3.1 Mobile Tagging in Marketing

The term mobile tagging refers to the process of scanning a code with a mobile device and displaying the stored information on the screen of that device. QR-Codes are the most popular codes applied for mobile tagging because they are easy to scan and have a high storage capacity. In the area of marketing, QR-Codes are combined with classical media, like journals, newspapers, or posters. A passerby, equipped with a smart phone and the respective software, can, for instance, scan a QR-Code on a poster in order to get interesting information about the advertised products and services. In many cases, a web-link is stored in the QR-Code which leads the interested person directly to the advertising company's website. As this example shows, the 2D-Technology enables potential customers to interact with an advertisement and furthermore allows the company to measure the success of an offline campaign because the code always contains information to its source (n.a. 2008). The fashion company Hennes & Mauritz (H&M), for example, integrates QR-Codes in their clothes and uses them for advertising purposes. In February 2010, the American broadcasting channel "The Weather Channel" advertised his Android-based application by using QR-Codes on TV and thus shows that QR-Codes are not restricted to paper-use but can be deployed in almost all media (Junior 2010).

Nowadays, 2D-Codes can even be branded and personalized by making the company's logo part of the Code. **Figure 4** shows a QR-Code which has been branded with the logo of the bank Sparkasse. The various ways of how shapes and colors can be integrated into a code, is displayed by the Microsoft Tag in **Fig. 5**.

3.2 Electronic Tickets and Boarding Passes

In order to prevent counterfeiting and to guarantee optical readability, Aztec-Codes are the first choice for electronic tickets and boarding passes. In this case, a passenger does not scan the 2D-code himself but receives the code, which represents his ticket, on his device. The mobile ticket is directly sent to his Internet-ready mobile phone by Email, MMS,

Fig. 4 QR-Code of Sparkasse (Ajung 2010)

or Text-Link. By following the provided link, the customer is forwarded to a website where his personal ticket is waiting for him. He can travel paperless because the 2D-Code on his phone is read by an appropriate scanner. The broad variety and diversity of mobile phones increases the technical complexity because neither the resolution nor the metrics of the displays have been standardized yet. The Aztec code addresses this problem in an appropriate way because it is read from the center to the outside. Therefore it is guaranteed that even codes that are larger than the display or are displayed in poor resolution can be read correctly. In April 2008, the airline Deutsche Lufthansa AG has introduced the electronic boarding pass. This enables the customer to order all flight related documents online, check in before arriving at the airport and travel paperless on most routes. This not only helps to lower costs in the ticket handling process but also increases the customer's convenience. 2D-Codes, especially the Aztec-Code, are also deployed in railway services: The German railways Deutsche Bahn as well as the Swiss railways Schweizerische Bundesbahnen use them for mobile ticketing.

3.3 Paper-Based Tickets and Boarding Passes, ID Documents

The 2D/Code PDF 417 is predestined for printouts because the paper size, in contrast to mobile phone displays, is standardized and almost no restrictions in terms of space need to be respected. The powerful error correction algorithm of the PDF417 allows for reconstructing a barcode, even if 50% of it is damaged. This Code is used for paper-based tickets and boarding passes as well as for American driving licenses.

3.4 Logistics and Production

If large data volumes need to be transferred in a machine-readable format, the DataMatrix-Code is the right choice. Although this code is established in nearly

Fig. 5 Microsoft Tag (Microsoft 2010)

all production-oriented industries, its main application area resides in marking electronic modules because it can be correctly read even in very small formats. Logistics is another application area where the DataMatrix-Code is wide spread. The German parcel service Deutsche Post AG, for example, prints the DataMatrix-Code on virtually all their consignments. As one of the first business customers of the Deutsche Post AG, T-Mobile changed the liberation of their mailings to the new standard DataMatrix-Code which allowed for generating the franking postal charges for large quantities of mails electronically. The client integrates the software that supports the liberation process into his distribution and logistics systems. Being enveloped, the liberated consignments are ready for shipment which saves time and costs. The code replaces the conventional stamp and the client does not pay until his mailing has actually been delivered. The code includes all shipment information of the post company and provides the telecommunication company with additional storage capacity for individual customer information. In doing so, T-Mobile optimizes its return management with the DataMatrix-Code (Deutsche Post 2006).

4 Summary and Outlook

2D-Codes have significant advantages compared to 1D-Codes. These are especially an increased memory capacity and error correction that favor 2D-Codes as a reliable technology to link the real and virtual world together. However, each 2D-Code has different characteristics and advantages. PDF417-Codes are primarily used for printouts, QR-Codes can – due to three positioning points – easily be read with mobile devices and Atztec-Codes can – due to a central positioning point – reliably be read from displays of different sizes. It can therefore be assumed that several codes will pass the test of time and each of them will be used in a specific usage scenario.

The limits of usage possibilities and capacities of 2D-Codes have not been reached yet. From a technological point of view, color information will soon be used as a third dimension that will significantly increase memory capacity and error correction (Microsoft 2010). Compared to current 2D-Codes, there is still room for improvement which will help to satisfy the increasing demand for memory capacity and data redundancy.

Radio Frequency Identification (RFID) technology can be seen as a direct competitor to 2D-Codes technology as it also provides an interface between the real and digital world. Even though RFID has certain advantages, such as visual contactless data gathering, 2D-Codes will nevertheless not disappear due to two main reasons. First, current mobile devices like mobile phones and handhelds fulfill all criteria to handle 2D-Codes. Regarding RFID, only a few prototypes are able to read RFID but are still not able to work as a transponder. Second, 2D-Codes are more cost-efficient then RFID chips. While 2D-Codes can be generated with a standard PC and a printer, the use of RFID requires expensive equipment and software.

In addition to technological development, there is also great potential regarding usability. The passive usage, for example the mobile boarding pass, is established in practice. However, customers are not accustomed to use their mobile devices to gather information actively. To improve this situation, pre-installed 2D-Code-readers and attractive offers could reduce the threshold and make the use of 2D-Codes a routine.

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