Cambridge University Press & Assessment
978-0-521-88839-4 — Barcodes for Mobile Devices
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Excerpt
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1 Introduction

1.1 Overview of barcode technology

First of all, it is important to know the relationship between a 'code' and a 'symbol' in this context:

> The shorthand used to represent the verbal description of an item is called the product identification code. The product identification code is shortened to the word 'code'. The use of the word 'code' should not be confused with the barcode, which is technically called the symbol. A barcode symbol is used to identify people and places as well as a product [1, p. 44].

1.1.1 Definition of barcode

The definition of a barcode is given in the International Organization for Standardization and the International Electrotechnical Commission (ISO/IEC 1976 2-2): Information technology – Automatic identification and data capture (AIDC) techniques – Harmonised vocabulary – Part 2: Optically readable media (ORM). Since it only includes one-dimensional barcodes, the definition given by the Japanese Standards Association (JSA) is preferred.

A barcode is a machine-readable representation of information that is formed by combinations of high and low reflectance regions of the surface of an object [2], which are converted to '1's and '0's. This definition includes both one-dimensional and two-dimensional barcodes. Originally, information was encoded into an array of adjacent bars and spaces of varying width and that is where the word 'barcode' is derived from. This type of barcode is called a linear one-dimensional (1D) barcode. The 1D barcode symbologies can be read by a scanner that sweeps a beam of light across the barcode symbol in a straight line [2].

By replacing the bars and spaces with dots and spaces arranged in an array or a matrix, the density of data within a given space can be increased. The resultant symbol is called a two-dimensional (2D) barcode. Unlike their 1D counterparts, the 2D barcode symbologies need a scanning device that is capable of simultaneous reading in two dimensions, i.e. vertically as well as horizontally. Strictly speaking, most 2D symbologies do not use bars for encoding data, and '2D code' may be more appropriate for symbologies of this class. However, in general both 1D and 2D barcodes are included as different forms of barcode technology, distinctive from other automatic identification technologies such as *radio frequency identification* (RFID). Hence, in this book, the term two-dimensional barcode (2D barcode) is adopted to describe symbologies that belong to this class of barcode technologies.

In addition to 1D and 2D barcodes, three-dimensional (3D) barcodes exist. A 3D barcode, also called a ‘bumpy barcode’, is any linear (1D) or 2D barcode that is directly embossed on the surface of a material [3]. Three-dimensional barcodes use spatial elements, or a bumpy aspect of symbols, to generate high and low reflectance instead of visual contrast between different colours. Since this type of barcode cannot be handled by mobile devices, 3D barcode technology is out of the scope of this book. Thus, it will be touched upon only when it helps to explain the entire barcode technology in relation to 1D and 2D barcode technologies.

The terms barcode symbology, barcode symbol and barcode label should not be confused with one another. A *barcode symbology* is a scheme or a set of rules for encoding information into a barcode format. A *barcode symbol* is a graphical representation of the symbology which is composed of symbol elements such as adjacent bars and spaces or dots and spaces. For example, a 1D barcode symbol includes a leading and a trailing quiet zone, a start and a stop character, data characters and checksum when required. A *barcode label* is a label that carries a barcode.

Barcode is also called ‘bar code’. Throughout this book, however, the term barcode will be used.

1.1.2 General anatomy of 1D and 2D barcodes

Numerous barcode symbologies have been developed and each has its distinctive features, as described in later chapters. However, there are common structural features shared by these barcodes. It is appropriate to present the anatomy of each type of barcode, namely, 1D and 2D barcodes, so as to provide a picture of each barcode technology.

Anatomy of 1D barcodes

In general, a 1D barcode symbol is made up of a start character, data characters, a stop character and quiet zones before the start character and after the stop character. Figure 1.1 presents the data structure of Code 128.

The following are brief descriptions of each component.

Quiet zone

The quiet zone is the area of high reflectance allocated before the start character and after the stop character of a 1D barcode symbol. The quiet zone is necessary for most barcode symbols to be reliably read and is included as part of the symbol. However, newly developed barcodes such as those of the GS1 DataBar family do not require quiet zones.

Start and stop characters

The start character is unique and is normally located at the leftmost edge of a horizontally oriented symbol. The stop character is also a unique character, located at the rightmost edge of a horizontally oriented symbol. These characters provide a scanner with reading

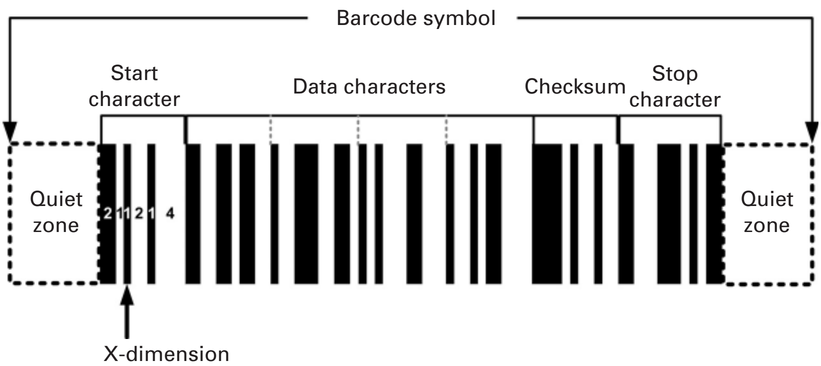

Fig. 1.1 General anatomy of 1D barcode: example – Code 128 symbol.

instructions such as the scanning direction and when to start or stop reading. The start and stop characters also allow barcode symbols to be read bi-directionally.

Checksum

Barcode symbols include a mandatory or optional checksum (also called the check character or check digit), whose value is used for the purpose of performing a mathematical check to ensure that the barcode is accurately decoded.

Data characters

The data characters or message characters appear after the start character. In Figure 1.1, four characters, !, 1, A, a, are encoded from left to right.

X dimension

The X dimension or module width is the dimension of the narrowest element (either bar or space) of a barcode symbol. The wider elements of the symbol are generally referred to as multiples of the X dimension. It is usually stated in mils, or one thousandths of an inch. In general, the larger the X dimension is, the more robust barcode reading can be achieved. However, a larger X dimension increases the size of a barcode symbol and, as a result, requires a wider space for printing. Most symbologies require that the quiet zone be 10 times the X dimension of the symbol, or one quarter of an inch, whichever is greater.

The data encoded in 1D barcode are vertically redundant. This enhances the reading robustness, allowing symbols to be read correctly even when they are partially damaged. The higher the bar heights, the greater the probability that at least one path along the barcode will be readable [3]. However, the bar height increases the amount of space required for printing symbols. In contrast, two-dimensional barcodes encode data not only vertically but also horizontally. This significantly increases the data capacity of 2D barcodes, yet they lack physical redundancy and thus have an inferior reading robustness.

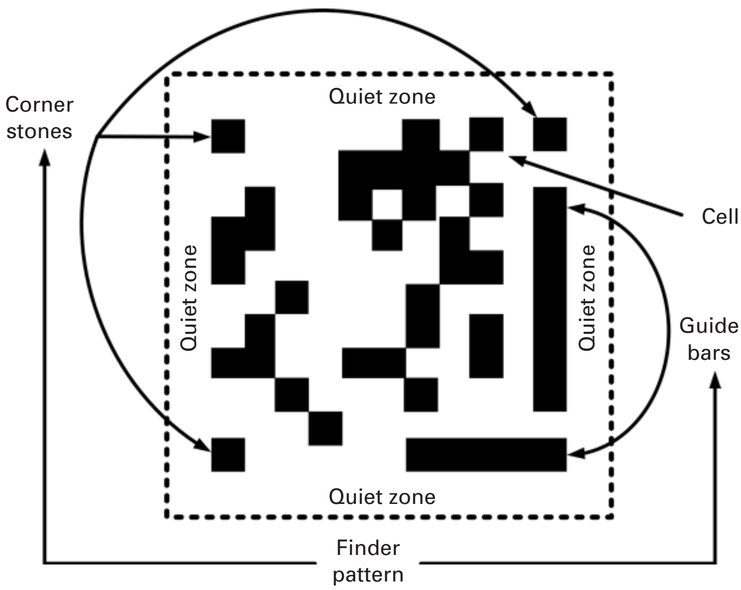

Fig. 1.2 General anatomy of 2D barcode: example – Visual Code symbol.

Anatomy of 2D barcodes

Currently a variety of 2D barcodes exist and some of them form distinctive shapes. However, most 2D barcodes, especially those used for mobile devices, are shaped as square arrays. With few exceptions, 2D barcodes contain common basic components: a finder pattern, a data area and a quiet zone surrounding the graphic symbol. Figure 1.2 presents the anatomy of an example 2D barcode called Visual Code.

Finder pattern

Each 2D barcode symbology has a unique finder pattern that is used to detect and locate the 2D barcode symbol. A finder pattern can be an L-shaped border, a square frame, a round cell located at the centre of the symbol, a plurality of dots arranged in a predetermined geometric pattern and so forth. A finder pattern is also used to compute the properties of a symbol (e.g. size, location and orientation) and correct them when required. In Figure 1.2, square cells at the three corners of the symbol (i.e. the corner stones) and two bars (i.e. the guide bars) comprise a finder pattern. In addition to the detection of the symbol, the corner stones are used to correct symbol distortion. The guide bars help to detect and correct the orientation of the symbol. Most 2D barcodes have error detection and correction capability, which increases the robustness of their reading. With an error detection and correction technique, the original data can be accurately retrieved even when the symbol is partially damaged, except when the finder pattern or part thereof is damaged. In the latter instance the barcode may not be successfully decoded or the barcode reading time may be increased significantly even if the barcode is eventually decoded successfully.

Data area

Within the graphical symbol in Figure 1.2, the area other than that occupied by the finder pattern is the data area. It comprises dots and spaces, called cells or sometimes modules, arranged in an array. The cells can be square, circular, triangular, hexagonal or any other geometric shape.

Quiet zone

Most 2D barcodes require a quiet zone surrounding the graphical symbol. The quiet zone helps detection of the barcode symbol, clearly separating the symbol from its background.

Most 1D barcodes work as an index to a backend database, encoding only a limited amount of data whereas most 2D barcodes can operate as a portable database, owing to their much greater data capacity. However, as a whole all barcode technologies have common advantageous and disadvantageous features.

1.1.3 Advantages and disadvantages of barcode technology

The 1D, 2D and 3D barcode technologies operate differently. Each has its strengths and shortcomings. In general, however, all barcode technologies have the following advantages and disadvantages.

Advantages

The advantageous features of barcode technology include the following:

(i) Fast, accurate and reliable keyless data entry can be achieved.
(ii) The technology is versatile and operates inexpensively using paper and ink.
(iii) The technology provides real-time information and allows the decisions to be made accordingly for ongoing operations.
(iv) Printed tags can last a long time without any deterioration. In a harsh environment, direct marking can be used.
(v) The barcode technology can offer secure operation. Once data are encoded in the format of a barcode, the data cannot be changed without physical alteration.

Disadvantages

There are some disadvantages in using barcode technology. The disadvantages of barcode technology are as follows:

(i) To read barcode symbols, a clear line of sight is required.
(ii) More than one barcode symbol cannot be read at a time.
(iii) Barcode technology does not have the ability to scan an object inside a container or a case.
(iv) The reading distance is rather short. Some scanners need physical contact to read the barcode symbols.

Each barcode format, i.e. 1D barcode, 2D barcode and 3D barcode, has its own advantages and disadvantages. Furthermore, each barcode symbology in any barcode format has its own advantages and disadvantages. These will be discussed in detail in Chapters 2 and 3. In the next section, the current use of barcodes will be introduced.

1.1.4 Barcode applications

The barcode technology is versatile and myriads of barcodes are used ubiquitously (see Appendix A). New barcode applications are being developed and introduced constantly. Instead of listing all the barcode applications currently in use, this book will provide the reader with information on where and how barcode technologies are used. The focus of the book is on the novel and innovative use of barcodes for mobile devices. Such applications are introduced in this chapter and discussed in greater detail in Chapter 4.

Point-of-sale systems in the retail, wholesale and grocery industries

The typical and most well-known barcode users have been retailers in the supply chain. At the point of sale (POS), they are the conduits as well as the key to the information flow [4]. In fact, retailers took the initiative in introducing barcode technology to the world.

The 1D barcodes called the *European Article Number* (EAN) and the *Universal Product Code* (UPC) have been main players for item identification at the POS. With EAN or UPC, also known as the International Article Numbering (IAN) or World Product Code (WPC), any item can be uniquely identified throughout the world. Owing to their limitation in data capacity, however, EAN and UPC will be replaced with the GS1 DataBar family, which will be explained in detail in Chapter 2.

The EAN and UPC barcode systems at POS provide accurate real-time information on products. This significantly improves the management of products, enabling efficient stock, inventory and shipping control.

Logistics in warehouses

While the products themselves are labelled with EAN or UPC, the cartons of products are usually labelled with specific symbologies for physical distribution. Interleaved 2 of 5 (ITF), a symbology that encodes packaging levels as well as the trade item number, is the most common approach in this area.

In recent years, Electronic Data Interchange (EDI), the standardised electronic format for business transactions, has been globally used in the field of physical distribution. In EDI, a 14-digit *Global Trade Item Number* (GTIN) encoded in ITF-14 is normally used as an identifier to look up product information in a database.

Barcode technology enables the efficient logistics management, for which accurate information on products such as name (or ID), quantity, price and location at a given time are required. In warehouses, for example, barcodes help to simplify inventory searching and control, prevent shipping mistakes, enable first-in first-out execution based on expiration-date control and improve traceability by means of manufacturing history control.

Manufacturing and industry

In the industrial sector, barcode symbologies that have the ability to encode extra data other than keys to a backend database have been preferred. Hence the early trend was to adopt 1D barcodes that are capable of encoding alphanumeric data such as Code 39 and Code 128. Since the invention of 2D barcodes, the trend has shifted to 2D symbologies, owing to their superiority in data capacity and efficiency in space.

Code 39 is mandated for some automotive industries and Department of Defense labels in the USA. Two-dimensional symbologies such as Data Matrix, QR Code, PDF417 and MaxiCode have also been used commonly in the automotive industry, owing to their greater data capacity. The Automotive Industry Action Group (AIAG) took the initiative in promoting 2D barcode technology throughout the industry. The AIAG developed specific application guidelines for specific 2D barcode use. It recommended Data Matrix for part marking and tracking, MaxiCode for freight sorting and tracking and PDF417 for general applications such as quality conveyance, production evidence, production broadcast, configuration management, material safety data sheets, shipping and EDI.

In manufacturing, 2D barcode technology has been adopted for two main reasons: part identification and product assembly process control. With 2D barcodes, each item can be accurately identified and tracked without accessing a database. Moving data files affixed to the products also enables the system to track an individual product throughout the assembly process and, as a result, to pinpoint the location of a problem and fix it. Such systems can save time and cost for product assembly, resulting in much greater productivity.

The electronic industry is also one of the pioneering users of 2D barcode technology. Such 2D barcodes as the Data Matrix, which can store data within a limited space, have been the best choice for electronic assemblies since free space on each item is scarce. In fact, the Electronic Industries Alliance (EIA) has specified Data Matrix in its component marking standard (EIA-706) and product marking standard (EIA-802). The former standard covers the use of 2D barcodes for marking electronic components of first-level assemblies, whereas the latter standard covers both labels and the direct marking of products, including the testing procedures for label-adhesive characteristics and mark durability. Two-dimensional barcodes can be used for component tracing, component tracking, automated manufacturing and process control, inventory and configuration management, automated inspection, quality control and testing, product marking and so forth.

Healthcare industry

The healthcare industry also showed an early interest in barcode technology. The importance of accurate data entry and identification is tremendous in the healthcare industry, where people's lives are at stake. A minor mistake could result in a tragic malpractice. Nonetheless, medical institutions are flooded with many different kinds of medicine and a variety of medical equipment. The expiration dates are fixed, for most of them, for safe and efficient use. Once they have expired they must not be administered or used no matter how costly they are. As a safety measure, efficient replenishment is necessary.

To ensure safe treatment and its continuous improvement, the establishment of traceability systems is very important. The data on a patient's treatment, for example, which medicines and/or equipment have been used, when and where, by whom and so forth, need to be precisely recorded. This can help to minimise escalation of the damage even when malpractice occurs. In response to these demands, barcodes can be used for:

(i) error and resultant malpractice minimisation;
(ii) inventory control and replenishment;
(iii) traceability systems; and
(iv) fast and accurate billing.

In the USA, since 1987 the Health Industry Business Communications Council (HIBCC) has administered the Health Industry Number (HIN) system to eliminate expensive and inefficient administrative cross-referencing tasks. The HIN, a randomly assigned nine-character alphanumeric identifier, is designed for identification of all trading partners when communicating with each other via computer [5]. It can identify not only specific healthcare facilities but also specific locations and/or departments within them [5].

For product identification, in 1995 the United States Department of Defense (DoD) mandated the use of the Universal Product Number (UPN) for the primary product identification of medical and surgical products [6]. Each product at all levels of packaging was to be assigned a unique UPN that can be created using either the Code 39 format standardised by HIBCC or the global standard format, GS1-128 (formerly known as UCC/EAN128). The UPN is beneficial for all interest groups, ranging from customers and manufacturers to distributors, since it facilitates the use of EDI, which, in turn, enhances simple, fast and accurate ordering and distribution.

The Food and Drug Administration (FDA) in the USA has managed and controlled drugs and medical devices using the National Drug Code (NDC) and the National Health Related Item Code (NHRIC). The former is used for identifying pharmaceutical products while the latter identifies medical and surgical devices. Both codes can be directly incorporated into the Global Trade Identification Number (GTIN) [6].

The movement for unambiguous identification of medical and surgical products throughout the supply chain also took place in Europe. In 1995, the European Health Industry Business Communications Council (EHIBCC) adopted the UCC/EAN128 (now known as GS1-128) format for labelling medical and surgical products, which has become the de facto global standard.

When very small items that cannot include linear barcode formats (e.g. unit-dose packaging) are to be labelled, space-effective, high-density, GS1 DataBar symbologies and 2D barcode symbologies such as MicroPDF417 and Data Matrix can be used instead.

Publishers

International Standard Book Numbering

The *International Standard Book Number* (ISBN) developed in ISO 2108/1972 is globally used for the numbering of published books. An ISBN, which used to be a unique 10-digit number, is assigned to each edition and variation of a book.

Table 1.1. The structure of the ISBN

Component	Number of digits	Assignor	Note
Prefix	3	GS1	978 or 979
Group identifier	up to 5	International ISBN Agency	A group of countries sharing a language
Publisher code	up to 7	National ISBN Agency	
Item number	up to 6	Publisher	
Checksum	1		Modulo 10 with 1× and 3× weighting on alternate digits

The International Article Numbering Association Number (EAN)[1] and the International ISBN Agency have reached agreement on the coordination of the EAN and ISBN systems. This coordination allows the EAN symbols to be used for representing ISBN numbers, by addition of the prefix digits 978 to the ISBN [4]. The prefix is assigned for the exclusive use of book coding throughout the world.

Since 1 January 2007, a revision to the ISO standard governing ISBNs has come into effect, which rules that unique 13-digit numbers shall be assigned for ISBNs. This is needed because there is a shortage of numbers in certain ISBN categories. It has led the ISBN to consist of 13 digits if assigned after 1 January 2007 and 10 digits if assigned before that. The former is called ISBN-13 and the latter ISBN-10. The ISBN-13 has the same format as the ISBN-10 when represented in the form of an EAN symbol. Table 1.1 presents the structure of ISBN-13. Removing the prefix from ISBN-13 numbers gives the structure of ISBN-10. The prefix 979 has been assigned by the ISBN agency as a future extension.

International Standard Serial Numbering

For a number of serial publications such as magazines, the *International Standard Serial Number* (ISSN) is used worldwide. The ISSN system was developed on the basis of ISO 3297/1975. The International Article Numbering Association EAN and the International Centre for the Registration of Serial Publications agreed on the coordination of EAN and ISSN systems [4]. The prefix 977 has been assigned to the ISSN agency for its exclusive use of coding periodicals and journals throughout the world.

Innovative and foreseeable barcode use

In recent years, the combination of two mobile technologies, namely, 2D barcodes and camera phones, is gaining popularity as a promising ubiquitous computing tool. With the built-in cameras, mobile phones can work as scanners, barcode readers and portable data storages while maintaining network connectivity. When used together with such camera phones, 2D barcodes work as a tag to connect the physical world and the digital world.

[1] EAN originally stood for European Article Number but, since its adoption as an international standard, it is now also used as an abbreviation for the International Article Numbering Association Number.

The most popular application is the linking of camera phones to Web pages via 2D barcodes. Such applications allow users to have 'always on' access to on-line activities and information such as on-line shopping and real-time information about public transport schedules and events. Saved on mobile phones, 2D barcodes can also be used as portable data files such as e-tickets or e-coupons. They can be purchased and exchanged via the Internet. E-tickets shown on the phone display can be scanned and verified at the check-in counter or reception with no attendants, which results in faster ticket handling. Furthermore, no paper is used, making the procedure environmentally friendly.

Considering the rapid improvements in reading distance as well as decoding reliability, availability and functionalities, applications that will allow camera phones to interact with 2D barcodes on a plasma display will no longer be a Utopian dream. With 2D barcodes, users can access the information they need at any time, anywhere, regardless of network connectivity. Numerous 2D barcodes have been developed to implement innovative applications, and this trend is continuing.

In Chapter 3, we describe 2D barcodes in greater detail; this is followed in Chapter 4 by a discussion on how barcode applications have evolved.

1.2 Organisation of the book

Since its first emergence, barcode technology has evolved significantly. Different types of barcode technologies have been developed and there is a variety of different barcode symbologies in each format. Each barcode symbology was developed to optimise its use for certain applications. In the first few chapters (i.e. Chapters 2–4), this book provides a comprehensive description of barcode technologies and some well-known barcode symbologies in each barcode format together with their application, with an emphasis on the 2D barcodes used for mobile applications. The latter chapters are dedicated to explaining the concept of barcode operation, followed by the development of a novel colour 2D barcode. They include an explanation of the technologies that improve the robustness of barcode symbols and their encoding and decoding algorithms (in Chapter 5), a novel colour 2D barcode development (in Chapter 6) and evaluation of the developed colour 2D barcode (in Chapter 7).