EVOLUTION OF BARCODE

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Abstract: *A barcode is an optical machine-readable representation of data, which shows data about the object to which it attaches. These days' barcodes have become very common for Unique Identification (UID) of almost everything from groceries to expensive goods.*

The mapping between messages and barcodes is called a symbology. The specification of a symbology includes the encoding of the single digits/characters of the message as well as the start and stop markers into bars and space, the size of the quiet zone required to be before and after the barcode as well as the computation of a checksum.

As every coin has two faces, every technology also has two faces i.e. the advantages and disadvantages. It depends on us (i.e; users & developers) which side we chose to explore!

Keywords: Barcode, 1D Barcode, 2D Barcode, Matrix Code, QR Code, Barcode Readers, UPC, CCD Reader

I. INTRODUCTION:

A barcode is an optical machine-readable representation of data, which shows data about the object to which it attaches [1]. Originally barcodes represented data by varying the widths and spacing's of parallel lines, and may be referred to as linear or one-dimensional (1D). Later they evolved into rectangles, dots, hexagons and other geometric patterns in two dimensions (2D). Although 2D systems use a variety of symbols, they are generally referred to as barcodes as well. Barcodes originally were scanned by special optical scanners called barcode readers; later, scanners and interpretive software became available on devices including desktop printers and Smartphone's.

II. HISTORY:

In 1948 Bernard Silver, a graduate student at Drexel Institute of Technology in Philadelphia, Pennsylvania, USA overheard the president of the local food chain, Food Fair, asking one of the deans to research a system to automatically read product information during checkout. Silver told his friend Norman Joseph Woodland about the request, and they started working on a variety of systems [3]. Their first working system used ultraviolet ink, but this proved too easy to fade and was fairly expensive.

Convinced that the system was workable with further development, Woodland left Drexel, moved into his father's apartment in Florida, and continued working on the system. His next inspiration came from Morse code, and he formed his first barcode from sand on the beach. "I just extended the dots and dashes downwards and made narrow lines and wide lines out of them." To read them, he adapted technology from optical soundtracks in movies, using a 500-watt light bulb shining through the paper onto an RCA935 photomultiplier tube (from a movie projector) on the far side. He later decided that the system would work better if it were printed as a circle instead of a line, allowing it to be scanned in any direction [1].

On 20 October 1949 Woodland and Silver filed a patent application for "Classifying Apparatus and Method", in which they described both the linear and Bull's-eye printing patterns, as well as the mechanical and electronic systems needed to read the code. The patent was issued on 7 October 1952 as US Patent 2,612,994. In 1951, Woodland moved to IBM and continually tried to interest IBM in developing the system. The company eventually commissioned a report on the idea, which concluded that it was both feasible and interesting, but that processing the resulting information would require equipment that was some time off in the future.

The first consumer product that introduced barcode was Wrigley's Gum [3].

III. SYMBOLOGIES:

The mapping between messages and barcodes is called a symbology [1]. The specification of a symbology includes the encoding of the single digits/characters of the message as well as the start and stop markers into bars and space, the size of the quiet zone required to be before and after the barcode as well as the computation of a checksum. Linear symbologies can be classified mainly by two properties:

- Continuous vs. discrete: Characters in continuous symbologies usually abut, with one character ending with a space and the

next beginning with a bar, or vice versa. Characters in discrete symbologies begin and end with bars; the inter-character space is ignored, as long as it is not wide enough to look like the code ends.

- Two-width vs. many-width: Bars and spaces in two-width symbologies are wide or narrow; the exact width of a wide bar has no significance as long as the symbology requirements for wide bars are adhered to (usually two to three times wider than a narrow bar). Bars and spaces in many-width symbologies are all multiples of a basic width called the module; most such codes use four widths of 1, 2, 3 and 4 modules.

Some symbologies use interleaving. The first character is encoded using black bars of varying width. The second character is then encoded, by varying the width of the white spaces between these bars. Thus characters are encoded in pairs over the same section of the barcode.

Stacked symbologies repeat a given linear symbology vertically.

The most common among the many 2D symbologies are matrix codes, which feature square or dot-shaped modules arranged on a grid pattern. 2-D symbologies also come in circular and other patterns and may employ steganography, hiding modules within an image (for example, Data Glyphs).

Linear symbologies are optimized for laser scanners, which sweep a light beam across the barcode in a straight line, reading a slice of the barcode light-dark patterns. Stacked symbologies are also optimized for laser scanning, with the laser making multiple passes across the barcode.

In the 1990s development of charge coupled device (CCD) imagers to read barcodes was pioneered by Welch Allyn. Imaging does not require moving parts, as a laser scanner does. In 2007, linear imaging had begun to supplant laser scanning as the preferred scan engine for its performance and durability.

2-D symbologies cannot be read by a laser as there is typically no sweep pattern that can encompass the entire symbol. They must be scanned by an image-based scanner employing a CCD or other digital camera sensor technology.

IV. TYPES OF BARCODES:

There are many types of barcodes that are used to track products, mail, and people. Nearly everyone has purchased products that have one or more barcodes. Barcodes have a permanent place in modern tracking systems. More advanced types of barcodes are being developed that will be more secure and will encode more data. Barcode systems such as the UPC system have already become a regular part of the daily life of many people.

Based on the type of the symbology that is used in the barcode, they are basically divided into two types. They are:

1. Linear (1D) Barcodes
2. Matrix (2D) Barcodes

These are the most commonly used types of barcodes. There are even 3D barcodes that are being developed.

A. LINEAR (1D) BARCODES:

Linear barcode is a first generation, "one dimensional" barcode that is made up of lines and spaces of various widths that create specific patterns. These patterns represent stock-keeping unit (SKU) numbers which are easily and quickly read by computer scanners. Continuous and discrete linear bar codes are still in common use today, also called UPC barcode.

The following table contains the list of some of the Linear Barcode Symbologies that are being used in various fields now-a-days.

Symbology	Continuous or discrete	Bar widths	Uses
U.P.C.	Continuous	Many	Worldwide retail, GS1-approved – International Standard ISO/IEC 15420
Codabar	Discrete	Two	Old format used in libraries and blood banks and on air bills (out of date)
Code 25 – Interleaved 2 of 5	Continuous	Two	Wholesale, libraries International standard ISO/IEC 16390
Code 128	Continuous	Many	Various – International Standard ISO/IEC 15417

Code 11	Discrete	Two	Telephones (out of date)
EAN-8, EAN-13	Continuous	Many	Worldwide retail, GS1-approved – International Standard ISO/IEC 15420
Facing Identification Mark	Continuous	One	USPS business reply mail
GS1 DataBar, formerly Reduced Space Symbology (RSS)	Continuous	Many	Various, GS1-approved
HIBC (HIBCC Health Industry Bar Code)	Discrete	Two	Healthcare – is a data structure to be used with Code 128, Code 39 or Data Matrix
Latent image barcode	Neither	Tall/short	Colour print film
Pharmacode	Neither	Two	Pharmaceutical packaging (no international standard available)
Intelligent Mail barcode	Continuous	Tall/short	United States Postal Service, replaces both POSTNET and PLANET symbols (formerly named One Code)
MSI	Continuous	Two	Used for warehouse shelves and inventory
PostBar	Discrete	Many	Canadian Post office
RM4SCC / KIX	Continuous	Tall/short	Royal Mail / Royal TPG Post
Telepen	Continuous	Two	Libraries (UK)

Table-1: Types of Linear Barcode Symbologies

B. MATRIX (2D) BARCODES:

A matrix code, also termed a 2D barcode or simply a 2D code is a two-dimensional way to represent information. It is similar to a linear (1-dimensional) barcode, but can represent more data per unit area [1].

A Data Matrix code is a two-dimensional matrix barcode consisting of black and white "cells" or modules arranged in either a square or rectangular pattern. The information to be encoded can be text or numeric data. Usual data size is from a few bytes up to 1556 bytes. The length of the encoded data depends on the number of cells in the matrix. Error correction codes are often used to increase reliability: even if one or more cells are damaged so it is unreadable, the message can still be read. A Data Matrix symbol can store up to 2,335 alphanumeric characters.

The following table contains the list of some of the Linear Barcode Symbologies that are being used in various fields now-a-days.

Symbology	Notes
3-DI	Developed by Lynn Ltd.
ArrayTag	From ArrayTech Systems.
Aztec Code	Designed by Andrew Longacre at Welch Allyn (now Honeywell Scanning and Mobility). Public domain. – International Standard ISO/IEC 24778
Chromatic Alphabet	An artistic proposal by C. C. Elian; divides the visible spectrum into 26 different wavelengths – hues.
Code 1	Public domain. Code 1 is currently used in the health care industry for medicine labels and the recycling industry to encode container content for sorting.
ColourCode	ColourZip developed colour barcodes that can be read by camera phones from TV screens; mainly used in Korea.
d-touch	readable when printed on deformable gloves and stretched and distorted
DataGlyphs	From Palo Alto Research Centre (also termed Xerox PARC).
Data Matrix	From Microscan Systems, formerly RVSI Acuity CiMatrix/Siemens. Public

	domain. Increasingly used throughout the United States. Single segment Data Matrix is also termed Semacode – Standard: ISO/IEC 16022.
Dot Code A	Designed for the unique identification of items.
EZcode	Designed for decoding by camera phones.
HueCode	From Robot Design Associates. Uses greyscale or colour.
JAGTAG	From JAGTAG, Inc. Optimized for use with mobile device cameras.
MaxiCode	Used by United Parcel Service. Now Public Domain
mCode	Developed by Nextcode Corporation specifically for camera phone scanning applications. Designed to enable advanced cell mobile applications with standard camera phones.
MicroPDF417	Facilitates codes too small to be used in PDF417.
MMCC	Designed to disseminate high capacity mobile phone content via existing colour print and electronic media, without the need for network connectivity
Nintendo e-Reader-Dot code	Developed by Olympus Corporation to store songs, images, and mini-games for Game Boy Advance on Pokémon trading cards.
Optar	Developed by Twibright Labs and published as free software. Aims at maximum data storage density, for storing data on paper. 200 kB per A4 page with laser printer.
PaperDisk	High density code, used both for data heavy applications (10 K – 1 MB) and camera phones (50+ bits). Developed and patented by Cobblestone Software.
QR Code	Initially developed, patented and owned by Toyota subsidiary Denso Wave for car parts management; now public domain. Can encode Japanese Kanji and Kana characters, music, images, URLs, emails. De facto standard for Japanese cell phones. Also used with BlackBerry Messenger to pickup contacts rather than using a PIN code. These codes are also used frequently for Android phones. – International Standard : ISO/IEC 18004
Secure Seal	Used in signature blocks of checks from the United States Treasury.
ShotCode	Circular barcodes for camera phones by OP3. Originally from High Energy Magic Ltd in name Spotcode. Before that probably termed TRIPCode.
WaterCode	High-density 2D Barcode(440 Bytes/cm^2) From MarkAny Inc.

Table-2: Types of Matrix Barcode Symbologies

V. BARCODE READER:

A handheld barcode scanner is a barcode reader (or barcode scanner) is an electronic device for reading printed barcodes [2]. Like a flatbed scanner, it consists of a light source, a lens and a light sensor translating optical impulses into electrical ones. Additionally, nearly all barcode readers contain decoder circuitry analyzing the barcode's image data provided by the sensor and sending the barcode's content to the scanner's output port.

VI. TYPES OF BARCODE READERS:

The reader types can be divided as follows:

A. PEN-TYPE READERS:

Pen-type readers consist of a light source and photodiode that are placed next to each other in the tip of a pen or wand. To read a bar code, the person holding the pen must move the tip of it across the bars at a relatively uniform speed. The photodiode measures the intensity of the light reflected back from the light source as the tip crosses each bar and space in the printed code. The photodiode generates a waveform that is used to measure the widths of the bars and spaces in the bar code. Dark bars in the bar code absorb light and white spaces reflect light so that the voltage waveform generated by the photo diode is a representation of the bar and space pattern in the bar code. This waveform is decoded by the scanner in a manner similar to the way Morse code dots and dashes are decoded.

B. LASER SCANNERS:

Laser scanners work the same way as pen type readers except that they use a laser beam as the light source and typically employ either a reciprocating mirror or a rotating prism to scan the laser beam back and forth across the bar code. As with the pen type reader, a photodiode is used to measure the intensity of the light reflected back from the bar code. In both pen readers and laser scanners, the light emitted by the reader is rapidly varied in brightness with a data pattern and the photodiode receive circuitry is designed to detect only signals with the same modulated pattern.

C. CCD READERS:

CCD (Charge Coupled Device) readers use an array of hundreds of tiny light sensors lined up in a row in the head of the reader. Each sensor measures the intensity of the light immediately in front of it. Each individual light sensor in the CCD reader is extremely small and because there are hundreds of sensors lined up in a row, a voltage pattern identical to the pattern in a bar code is generated in the reader by sequentially measuring the voltages across each sensor in the row. The important difference between a CCD reader and a pen or laser scanner is that the CCD reader is measuring emitted ambient light from the bar code whereas pen or laser scanners are measuring reflected light of a specific frequency originating from the scanner itself.

D. CAMERA-BASED READERS:

Two-dimensional imaging scanners are the fourth and newest type of bar code reader. They use a camera and image processing techniques to decode the bar code.

A. VIDEO CAMERA READERS:

Video camera readers use small video cameras with the same CCD technology as in a CCD bar code reader except that instead of having a single row of sensors, a video camera has hundreds of rows of sensors arranged in a two dimensional array so that they can generate an image.

B. LARGE FIELD-OF-VIEW READERS:

Large field-of-view readers use high resolution industrial cameras to capture multiple bar codes simultaneously. All the bar codes appearing in the photo are decoded instantly or by use of plug-ins (e.g. the Barcodepedia uses a flash application and some web cam for querying a database), have been realized options for resolving the given tasks.

E. OMNI-DIRECTIONAL BARCODE SCANNERS:

Omni-directional scanning uses "series of straight or curved scanning lines of varying directions in the form of a starburst, a lissajous pattern, or other multi-angle arrangement are projected at the symbol and one or more of them will be able to cross all of the symbol's bars and spaces, no matter what the orientation."

Omni-directional scanners almost all use a laser. Unlike the simpler single-line laser scanners, they produce a pattern of beams in varying orientations allowing them to read barcodes presented to it at different angles. Most of them use a single rotating polygonal mirror and an arrangement of several fixed mirrors to generate their complex scan patterns.

Omni-directional scanners are most familiar through the horizontal scanners in supermarkets, where packages are slid across a glass or sapphire window. There are a range of different Omni-directional units available which can be used for differing scanning applications, ranging from retail type applications with the barcodes read only a few centimetres away from the scanner to industrial conveyor scanning where the unit can be a couple of meters away or more from the code. Omni-directional scanners are also better at reading poorly printed, wrinkled, or even torn barcodes.

F. CELL PHONE CAMERAS:

While cell phone cameras without auto-focus are not ideal for reading some common barcode formats, there are 2D barcodes which are optimized for cell phones, as well as QR Codes and Data Matrix codes which can be read quickly and accurately with or without auto-focus. These open up a number of applications for consumers:

- Movies: DVD/VHS movie catalogues
- Music: CD catalogues play MP3 when scanned
- Book catalogues and device.
- Groceries, nutrition information, making shopping lists when the last of an item is used, etc.
- Personal Property inventory (for insurance and other purposes) ode scanned into personal finance software when entering. Later, scanned receipt images can then be automatically associated with the appropriate entries. Later, the bar codes can be used to rapidly weed out paper copies not required to be retained for tax or asset inventory purposes.
- If retailers put barcodes on receipts that allowed downloading an electronic copy or encoded the entire receipt in a 2D barcode, consumers could easily import data into personal finance, property inventory, and

grocery management software. Receipts scanned on a scanner could be automatically identified and associated with the appropriate entries in finance and property inventory software.

- Consumer tracking from the retailer perspective (for example, loyalty card programs that track consumers purchases at the point of sale by having them scan a QR code).
- Access control (for example, ticket validation at venues), inventory reporting (for example, tracking deliveries), and asset tracking (for example, anti-counterfeiting).

G. SMARTPHONE'S:

Smartphone's can be used in Google's mobile Android operating system via both their own Google Goggles application or 3rd party barcode scanners like Scan. Nokia's Symbian operating system features a barcode scanner which can scan barcodes, while mbarcode is a barcode reader for the Maemo operating system. In the Apple iOS, a barcode reader is not natively included but more than fifty paid and free apps are available with both scanning capabilities and hard-linking to URI. With BlackBerry devices, the App World application can natively scan barcodes. Windows Phone 7.5 is able to scan barcodes through the Bing search app.

H. HOUSING TYPES:

The housing type reader packaging can be distinguished as follows:

A. HANDHELD SCANNER:

A handheld scanner is a barcode scanner with a handle and typically a trigger button for switching on the light source to read the barcode.

B. PEN SCANNER (OR WAND SCANNER):

A pen-shaped scanner is a barcode scanner that is swiped to read the barcode. These types of scanners are similar to handheld scanners, except that the size & shape of these scanners will be in the form of a pen/wand.

C. STATIONARY SCANNER:

Wall or table mounted scanners that the barcode is passed under or beside. These are commonly found at the checkout counters of supermarkets and other retailers.

D. FIXED-POSITION SCANNER:

An industrial barcode reader used to identify products during manufacture or logistics. Often used on conveyor tracks to identify cartons or pallets which need to be routed to another process or shipping location. Another application joins holographic scanners with a checkweigher to read bar codes of any orientation or placement, and weighs the package. Systems like this are used in factory and farm automation for quality management and shipping.

E. PDA SCANNER (OR AUTO-ID PDA):

A PDA scanner is a PDA with a built-in barcode reader or attached barcode scanner which reads the barcode.

F. AUTOMATIC READER:

An automatic reader is a back office equipment to read bar-coded documents at high speed (50,000/hour).

G. CORDLESS SCANNER (OR WIRELESS SCANNER):

A cordless barcode scanner is operated by a battery fitted inside it and is not connected to the electricity mains

VII. PROS & CONS OF BARCODE TECHNOLOGY:

As every coin has 2 sides, every technology also has 2 sides' i.e; pros & cons. It depends on how effectively the cons have been handled which determines whether a technology is here to stay of just a fad.

Basically there are many pros & cons of barcode technology. Here let us discuss about only 4 of them, which are most commonly pointed. The 1st 2 aspects discussed below are the pros of barcode technology & the next 2 aspects are the cons of barcode technology. Instead of considering them as cons, we can consider them as a small cost that has to be paid for such a beautiful & nice technology like barcode which makes many of our tasks simpler & easier.

A. TIME:

In the blink of an eye, scanning a bar code instantly displays the product name, type of product and price. Bar codes also have a 12-digit product number that when entered also produces the same information. However, if a cashier has a long line of impatient customers, entering the product details of each item is time-consuming, especially in grocery stores

where each customer usually purchases multiple items. Although bar codes are a huge advantage when it comes to time, it can also be a disadvantage if the bar code on the product doesn't correspond to the right product, or the bar code scanner isn't working.

B. INVENTORY:

Inventory is a huge component of any goods and services business. Keeping track of inventory can be a tedious, time-consuming and difficult task to do without a bar code scanner. With a bar code scanner, shop owners simply scan the bar code on the items and keep track of the store's inventory that way. When an individual purchases an item, the scanner transmits this information to the computer and it's calculated on the stock inventory via computer technology. The major disadvantage here is if the cashier sees a number of items that look or seem the same and scans one item multiple times to save time. Each item and type of item has a unique bar code and must be scanned separately. As a result, this could affect inventory.

C. LABELS:

Labels make it easy for bar code scanners and computers to recognize the product item and vendor name. But when a label is damaged or non-existent, it poses problems. Damaged labels make it difficult for the cashier to scan. Even the 12-digit number on the label may be damaged to the point where it is not legible. When this occurs, the checkout process is significantly delayed while the same product is sought out and brought to the cashier for scanning. In addition, some products, such as fruits and vegetables at grocery stores, don't have labels, which potentially cause delay. However, cashiers are usually trained to remember the 12-digit number corresponding to items without labels.

D. TRAINING:

While bar code technology drastically reduces the time and energy spent on inventory and checkout procedures. Businesses that want to implement bar code equipment and technology have to withstand the growing pains of doing so. This includes training employees, installing the equipment, expensive printers and the time spent entering codes for labels. However, despite the disadvantages with start-up, the bar code technology benefits businesses in the long run.

VIII. CONCLUSION:

Fads come and go. Those that have “staying power” become trends that inevitably provide benefit to organizations or society as a whole. Bar code, now 60 years old and counting, is well beyond a fad. The benefit of bar code has often been to enable “visibility” of items or people. These important things are tracked and accounted for, automatically.

It is difficult to predict the exact application of bar code into the future, however one fact is for sure - trends that we see forming today will set the stage for the use of the technology by our children. For instance, the Department of Defence (DoD) is leveraging 2D bar code to track mission critical and valuable items. What the DoD calls Principle End Items (PEIs) is the tip of the iceberg for barcode. Vehicles, aircraft, major weapon systems, support equipment all fall into this category. This will evolve into marking and accounting for less valuable items and less mission critical items as the technology infrastructure is deployed (Barcode software, networks, mobile computers with barcode scanners, and barcode printers). The demand for visibility on the most critical and the most expensive items always lead in the use of auto ID technology such as barcode, however the need of visibility into less critical and valuable assets always follow.

Take for instance, package tracking. The need for small parcel tracking has always been driven by the most valuable items and visibility in transit. In the early 80’s, small parcel tracking moved high valued items. When it was critical to ship an item such as a critical spare part to keep a manufacturing assembly line running, you used a carrier such as FedEx or UPS. Today, we ship many items via small parcel carriers, even something as inexpensive as a book from Amazon.

Back to the DoD for a moment, You’ll notice that these PEIs are getting all of the attention but you’ll soon see barcode gravitate to smaller and smaller components that make up the end item. Everything will soon have a barcode and scanning these components will be just as ordinary as ordering a book from Amazon.

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