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The Trends of Optical Data Capturing Techniques and Application Areas

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Abstract
In this paper, an intensive study has been carried out on various techniques and trends in evolution of Optical Data Capturing Techniques and its applications. Overview of various dimensions in Automatic Identification and Data Capturing Technique is followed by in-depth analysis of one and two-dimensional Optical Data Capturing Techniques (ODCT). Advantages, limitation and comparison on various parameters, of various ODCT has been discussed in the paper. The models for effective and efficient usage of these techniques have been discussed, originating from traditional usage to usage in smart applications and advancing to present and potential future trends in security and recognition applications. Paper explains the modular architecture for efficient usage of ODCT for correct and effective implementation. The paper is concluded with probable future trends in this domain and discusses various dimensions that this technique may exploit.

Keywords: Automatic Identification and Data Capturing Technique, one-dimension codes, two-dimension codes, application data capturing techniques, barcodes, smart applications of two-dimensional codes.

Introduction

The field of Optical Data Capturing Technique is ever evolving. Since its inception in 1952, it is being widely used in supply chain management, supermarkets, advertisements, software, mobile apps and many more varied fields. The continuous development in its efficiency has made it omnipresent and has led it to be used in many new technological innovations. Few factors in its wide acceptance includes its simplicity, flexibility, standardization, responsivity, accuracy, mobility etc. These factors have helped them in being universally accepted. The existence of Optical Data Capturing Techniques over more than 65 years proves the potential this technique has and motivates us to understand and study trends of this technology.

Optical Data Capturing Techniques provides a quick, accurate and cost-effective way to collect and enter data in addition to various other functionalities. The high density of smartphones in today's world has given a new horizon to the ways in which these techniques can be used for various applications. Smartphone has provided the user with handheld high-quality image capturing means and computing ability, which can/is acting as catalyst for future usage of more efficient and complex data capturing techniques. Its ability of error free, quick and cost-effective collection/ entry of data to almost any micro-controlled device and ability of tagging the backend data is far from fully exploited.

This paper aims to explain the trends in optical data capturing techniques from one dimension to two dimensions and explores the feasibility of adding dimension to it. We have enumerated the features of the various techniques and comparative analysis for these techniques has been done. The trends of its application in the present and past is studied, and architecture of possible future application is suggested. Analysis and feasibility study of adding dimensions to the existing and proposed data capturing techniques to improve functionalities and increase data density has been done.

Background

Optical Data Capturing Techniques are subfield of Automatic Identification and Data Capture (AIDC), AIDC refers to methods of automatically identifying objects, collecting data about them and entering data into computing system [1].

AIDC technology can be broadly divided into four categories [1]:-

(a) Optical/printed
  (i) 1-D Codes
  (ii) 2-D Codes
  (iii) Printed
    (aa) Optical Character Recognition (OCR)
    (ab) Optical Mark Recognition (OMR)

(b) Electro-Magnetic
  (i) Radio Frequency Identification
  (ii) Magnetic Ink Character Recognition (MICR)
  (iii) Electronic Article Surveillance (EAS)

(c) Biometric
(d) Electronic
  (i) Contact Memory
  (ii) Machine Vision

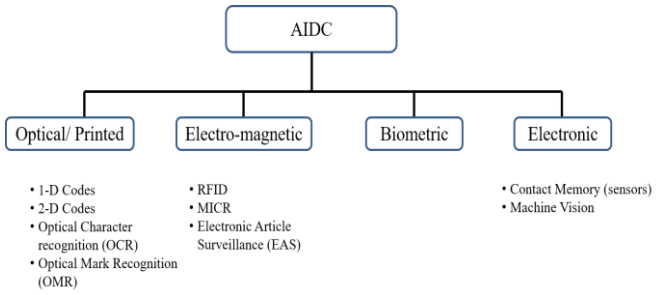

Figure 1: Automatic Identification and Data Capturing (AIDC) categories

Brief overview and comparative chart of various AIDC technology is as described in table 1

Table 1 : Comparative chart AIDC technologies

	COMP-LEXITY	CONT-ENT	COST	APPLICATI-ONS	ROBU-STNESS	EXAMP-LE
PRINTED	Least	Medium	Least	•Software •Advertisements •Data tagging •Product info	High	•Barcodes •OCR •OMR
ELECTRO-MAGNETIC	Medium	High	Mediu m	•Security •Product information •Data tagging	Medium	•RFID •MICR
BIOMETRI C	High	Least	High	•Security •Authentication •Role based access	Low	•Fingerprin t •Retina
CHIP BASED	High	High	High	•Sensors •IoT •High end applications	Low	•Location, temperatur e Sensors

This paper covers Optical Data Capturing Techniques, which traditionally has been subdivided into two symbology, one-dimension or linear codes and two-dimension codes. However, because of ever growing requirement of increase data capacity and adding functionalities there is trend of exploring more dimensions in this field, we in this paper will study about existing dimensions and adding dimensions to this technique. Figure 2 brings out the existing and possible future dimensions in this technique.

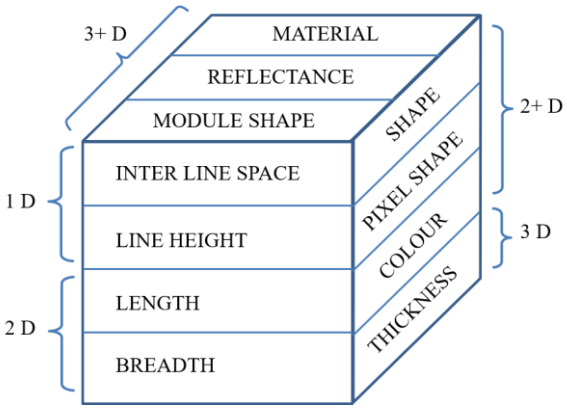

Figure 2: Dimensions of ODCT

One-Dimension or Linear codes

One dimension or linear codes encodes characters into linear series of black lines and spaces, first patent on this was awarded to Woodland and Silver in 1952. Encoding is done in one spatial dimension for mapping between message and linear symbology. The two forms of one dimension or linear codes are width modulated codes and height modulated codes [2].

Width modulated codes

Symbols consisting black and white lines of varied width representing various characters, Universal Product Code is a widely used example of one dimensional or linear code.

Height modulated codes

It consists of varied height bars and spaces, it was used by US postal service for ZIP code identification.

Various types of commercial one dimensional or linear codes are Code 39 [3] (ISO/IEC 16388) Code 128 [4] (ISO/IEC 15417) UPCa, UPCe EAN8, EAN13, Databar, USPS IMB

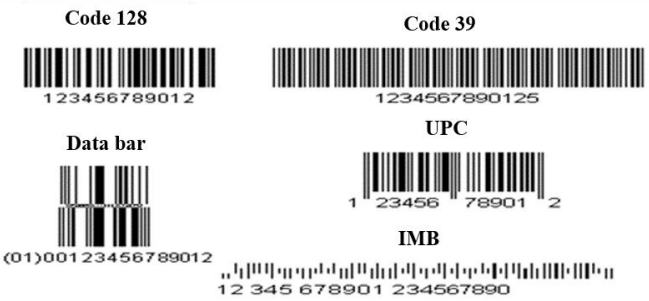

Figure 3: Commercial One Dimensional or linear code

working of one dimension or linear code can be summarized as shown in figure 4.

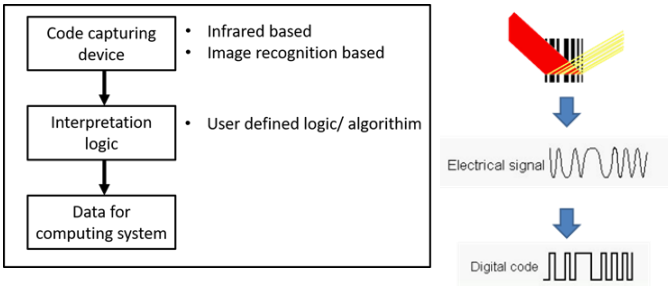

Figure 4: Working of One Dimensional or linear code Data Capturing Technique

One-dimensional codes have been widely accepted because of its simplicity, faster identification, less complicated equipment involved and being highly cost effective. However, these codes have limitations, as, for its working direct line of sight is required, it can be processed one item by one item only, has limited storage capacity, is read-only and requires very specific reading/ scanning device.

Comparison of various one-dimensional code is as brought out in table 2

Table 2: Comparison of various one-dimensional or linear code [4][7][8]

	Example	Standar disation	Coding capabilit y	Type	Charact er capacity	Variation	Applications
Code 128		ISO/IEC 15417: 2007	ASCII character	Width modulated	48 char (GS 1)	128A 128B 128C	Supply chain management
UPC		GS 1	Numeric	Width Modulated	6-12 Numeric	UPC A UPC E	Retail products
EAN		GS 1	Numeric	Width Modulated	8-13 Numeric	EAN-13 ISBN ISSN	Retail products
IMb		USPS-B-3200	Numeric	Height Modulated	31		Postal Departments

Two dimensional codes

The success and efficiency of one dimensional codes and requirement of higher data density, motivated evolution of two dimensional codes. The limitation of linear code of being a portable database in a small area was overcome by the two-dimensional codes. Two-dimensional code extended the advantage of being fast, accurate, more data density, inexpensive, easy encoding and decoding. These advantages led to wide use of these codes in software applications, medical industry, electronic industry apart from usage in areas where one dimensional codes were already being used. The evolution of two-dimensional codes is summarized in figure 5 [9][10][11][12][13][14].

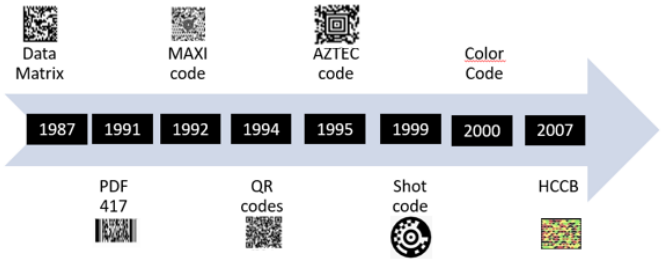

Figure 5: Timeline – evolution of two dimensional codes

Working of two-dimensional codes can be summarized with the help of figure 6

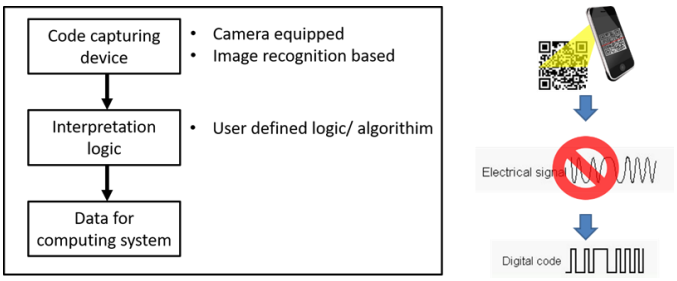

Figure 6: Working of One Dimensional or linear code Data Capturing Technique

Like one dimensional codes two-dimensional codes are subdivided in two categories Stacked Two-Dimensional Codes and Matrix Two-Dimensional Codes [15].

Stacked two-dimensional codes

One-dimensional or Linear codes were stacked on top one another or layered vertically to create the stacked two-dimension codes. Higher density than one-dimensional or linear codes was achieved. Stacked codes were optimized for reading with laser scanner. Example of stacked two-dimensional code includes PDF 417, Code 49, Code 16Kcoda block UltraCode.

Matrix Two-Dimensional Codes

Matrix codes are two dimensional codes in true sense, rather than layering of codes as stack, matrix code store the data as black and white equal dimension spots in a matrix. Matrix codes usually incudes pattern for orientation, format, timing size and printing density.

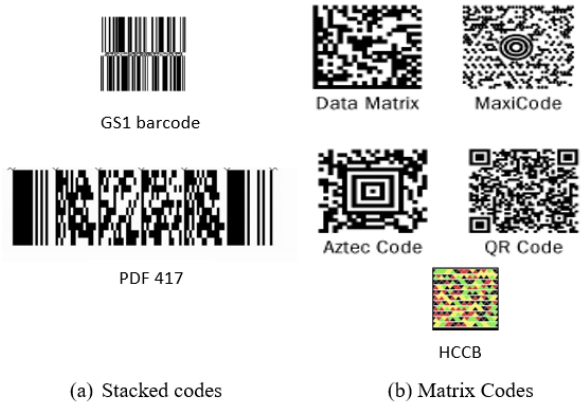

Figure 7: Examples of stacked and matrix codes

Example of two-dimensional codes

Data Matrix

Data Matrix [9] is a high density 2-dimensional barcode patented in 1991, it is standardized by ISO/IEC 16022E. Data matrix is variable in size giving advantage over fixed architecture barcode symbols, it can encode up to 3116 characters from the entire 256-byte ASCII character set. The symbol is built on a square grid which have a finder pattern around the edges of the symbol to allow a scanner to identify the barcode. The finder pattern makes it possible to read the barcode regardless of the physical orientation of the code. Data matrix supports varied size, structure append and data compaction before encoding.

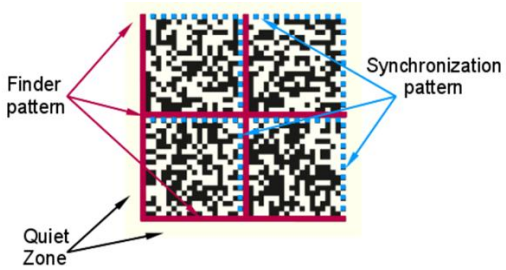

Figure 8: Structure of data matrix symbol

QR codes

QR code[12] was developed and patented by Denso Wave in 1994. It focused on improving speed of the complex structured 2D barcodes. It supports low resolution scanning with less decoding complexity. QR code has 40 versions beginning with 21 x 21 pixels to 177x177 pixels. QR code supports four level of error correction L (upto 7%), M (upto 15%), Q (upto 25%) and H (upto 30%). Maximum Data capacity of QR code (version 40) is 7,089 characters for numeric only, 4,296 characters for alpha-numeric, 2,953 bytes and 1817 characters for Kanji.

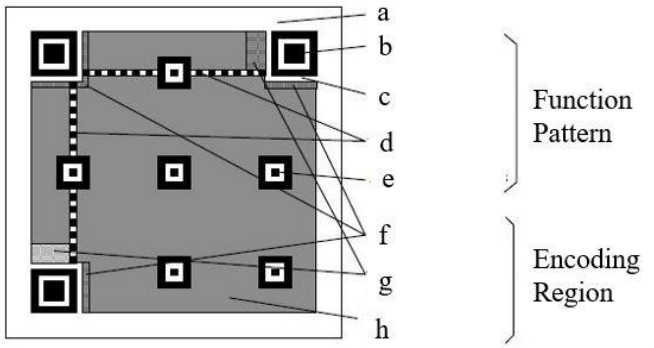

Figure 9: Structure of QR Code symbol
(a)Quiet zone (b) Finder Pattern (c) Separator (d) Timing Pattern (e) Alignment Pattern (f) Format Information (g) Version Information (h) Data and ECC

In addition of error correction and data storage functionalities QR code supports following functionalities [12]

Structured append

This feature of QR code allows the long input, more than the capacity of one QR code, to be encoded in more than one QR code (maximum 16). While decoding the result will give the data same as input no matter, in what sequence they were read by the scanner. In other words, if there is input data which is more than the capacity of one QR code then, the same continuous data can be divided into different QR codes with ability of decoding it into data same as input data.

Extended Channel Interpretations

One of the most useful feature which distinguishes QR code from other 2D symbols, it allows encoding any character sets (e.g. Greek, Hindi, Arabic etc.) or any other industry-specific requirements.

Reflectance reversal

This functionality allows symbols to be read even when image is either dark on light or light on dark i.e. the reader will produce the same results when black and white module are transposed.

Mirror imaging

This feature makes it possible to achieve a valid decode of a symbol in which the arrangement of the modules has been laterally transposed like as if the QR image has been mirrored either from sides or top, the effect of mirror imaging is interchange of row and column positions of the modules.

PDF 417

PDF 417 [10] are stacked one dimensional or linear codes published by Symbol Technologies and are standardized by ISO/IEC 15438 standard [10]. The data density depends upon compaction mode, number of column and rows, error correction level. The data capacity of PDF 417 is 2710 digits in numeric compaction mode 1850 characters in text compaction mode 1108 bytes in byte compaction mode. One barcode can hold up to a maximum of 929 codewords (data count + data + error correction). PDF stands for Portable Data File, each pattern in the code consists of 4 bars and spaces, and each pattern is 17 units long making it PDF 417 codes.

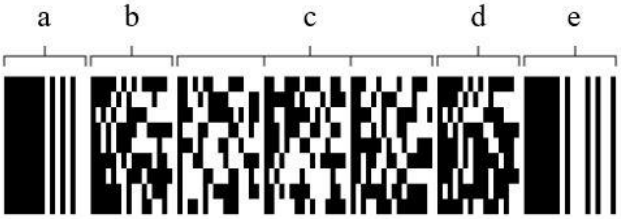

Figure 10: Structure of PDF 417 Code symbol
(a) Start Pattern (b) Left Row Indicator Codewords (c) Data Codewords (d) Right Row Indicator Codewords (e) Stop Pattern

Start and stop pattern

To find the start and end of the barcode. These are same for all codes.

Left and right row indicators

For orientation of the reader device. Change according to actual data in the barcode to achieve maximum contrast.

Data and data count

Unique for each barcode and depends on encoded data. This pattern is group of bars and spaces representing one or more numbers, letters, or other symbols.

Two+ dimension codes

The ever-growing requirement of higher density supported by better user-side technology led to exploration of two+ dimensions, in 2000, T Don Han et al. developed color code and have patent no US Patent 7,020,327. A standard color code encodes 10 digits and comprises a matrix of 5x5 cells having combination of four different colors black, blue, green and red.

HCCB (High Capacity Color Barcode)

Established in 2007, these are propriety code by Microsoft. HCCB [14] has color Triangle symbols for efficient packing, and has 2, 4 and 8 colors flavors. According to information available [14] 2,000 binary bytes, or 3,500 alphabetical characters per square inch was achieved in laboratory tests in its highest density form using a 600dpi business card scanner.

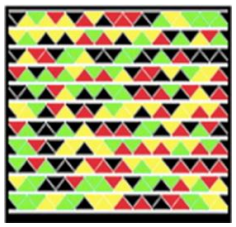

Figure 11: HCCB Code symbol

Table 3 brings out the comparative study for the above discussed two-dimension codes [9][10][12][14]

Table 3: Comparison Two-Dimensional Optical Data Capturing Techniques

	PDF 417	DATA MATRIX	QR CODES	HCCB
EXAMPLE				
STANDARDS	ISO/IEC 15438	ISO/IEC 16022	ISO/IEC 18004	Patented
MAX CAPACITY	1850 Chars	2,335 Chars	7,089 Chars	3,500 alphabetical chars/ sq inch
ERROR CORRECTION LEVELS	9	1 (3 compaction modes)	4	Patented
POPULAR APPLICATIONS	Travel, postal industries	Electronics, automotive industries	Software application	Patented
TYPE	Stacked	Matrix	Matrix	Matrix
DIMENSION	2 D	2 D	2 D	2+ D
VERSIONS	1	200	40	Patented
SPECIAL FEATURE	High Capacity	Printable in Small size	High Capacity, Scanning speed	High capacity

Application trends

Traditional Method

Figure 12: Traditional applications of Optical Data Capturing Techniques

In traditional applications the data is stored in form of Black and White modules then using the scanner the data is read and transmitted to the micro-controlled device which is suitably processed or stored by the software or applications. The most common example of the same we see in supermarkets on various products.

Smart Applications

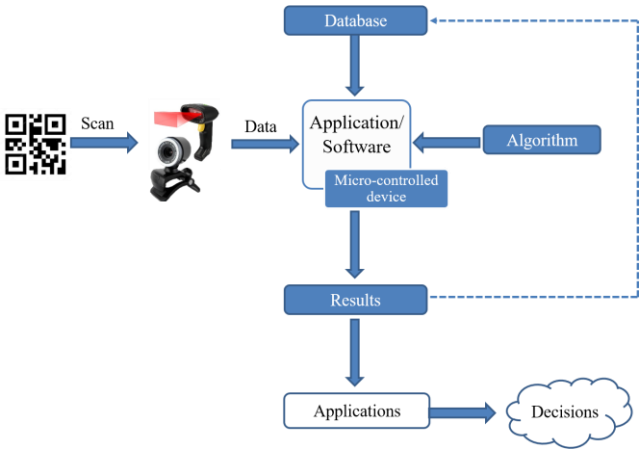

Figure 13: Smart applications of Optical Data Capturing Techniques

In these applications, stored data in form of black and white modules is read by the scanner and transmitted to micro-controlled device where application with the help of algorithm and database computes the result which will act as input to other application for decision making. Example of these applications are Survey Study, advertisement analysis etc.

Application of this architecture also include it use in Augmented Reality and virtualization as well [16]. These application goes a step ahead for exploitation of the potential of ODCT in different environments.

Recognition or Security application

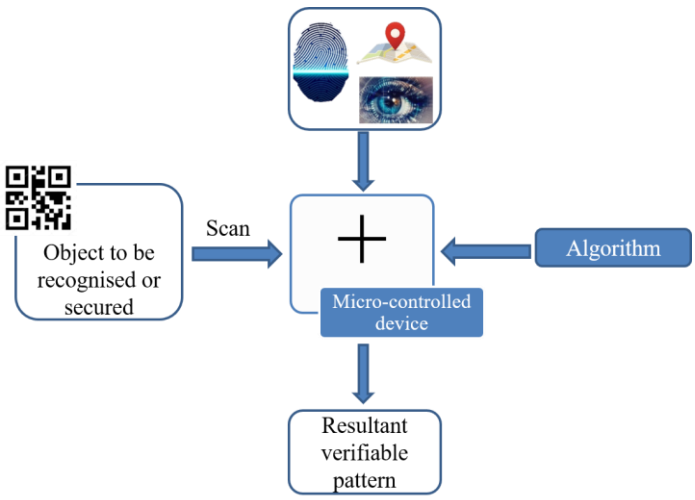

Figure 14: Applications of Optical Data Capturing Techniques for authentication

Application of Optical data capturing technique are vast, this technique can be used in combination with other technologies, figure 14 describes the usage of Optical Data Capturing Techniques for recognition/ securing/ locating the object or subject.

Barcodes tagged object on scanning extends information about the object which can further be combined with the location or biometric identification method for further use by the user or other applications. This method can be used for authentication.

Example of these application include recent cycle hiring app PEDL [17], ATM/debit card of Indian post has used this method in place of magnetic strip, Aadhaar card etc.

Future: multi-dimensional codes

Three-dimension codes

The availability of high end 3-D cameras and printer makes it possible for us to think and explore feasibility and standardization of Three-dimensional codes or Data Capturing Techniques. With each dimension increase, the information content in the code within given area will increase exponentially. Three-dimensional code can be embossed on a surface or can be printed/ manufactured separately, encoding can be based on varying height and width of each pixel. These codes can be used to be embedded into the material as well [18].

Figure 15: Example of 3D code[19]

Three+ dimension codes

Within the three-dimension codes pixels color, material and shape can be varied to further explore the feasibility of adding dimension and increasing the data content in the code.

Conclusion

The field of optical data capturing technique is full of potential, its ability of converting printed information to digital information gives it an unmatchable edge as a technique. Researcher's and Industry's continuous efforts for increasing its data handling capacity and its applications in real world is making it an interesting and upcoming technology. In this paper we have described the evolution and presented brief overview of working of one and two-dimensional codes. Comparison of various commercially available one and two-dimensional codes has been presented. Various application methodologies of these techniques have been explained with the help of modular architecture for its usage in varied fields. Future possibilities with three and three+ dimension codes of data capturing techniques have been explained in brief. The future of Optical Data Capturing Technique lies in adding dimension to increase the data capacity as well as the functionalities and the application areas.

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