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Understanding 2D-BarCode Technology and Applications in M-Commerce – Design and Implementation of A 2D Barcode Processing Solution

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Abstract

With the swift increase of the number of mobile device users, more wireless information services and mobile commerce applications are needed. Since various barcodes have been used for decades as a very effective means in many traditional commerce systems, today people are looking for innovative solutions to use barcodes in the wireless world. Recently, the mobile industry began to pay more attention to barcode applications in m-commerce because 2D-barcodes not only provide a simple and inexpensive method to present diverse commerce data, but also improve mobile user experience by reducing their inputs. This paper first discusses 2D-Barcode concepts, types and classifications, major technology players, and applications in mobile commerce. Then, it reports a research project to develop a 2D-Barcode Processing solution to support mobile applications. Moreover, the paper also presents the application examples, and case study using the solution.

Keywords: mobile commerce, 2D-barcode processing, 2D-barcode technology, and 2D-Barcode enabled mobile applications.

1. Introduction

As the significant increase of mobile device users, more wireless information services and mobile commerce applications are needed.

In the past decade, various barcodes have been used as a very effective means in many traditional e-commerce systems, supply-chain management, retail sale-and-buy, as well as tracking and monitoring of products and goods. Today, many people believe digital barcodes provides an effective means for mobile commerce application systems due to the following reasons:

- Using digital barcodes provides a simple and inexpensive method to present diverse commerce data in electronic commerce and m-commerce, including product id and the detailed product information, advertisements, and purchasing and payment information.
- As more mobile digital cameras are deployed on mobile devices, using digital barcodes is becoming an effective way to reduce the mobile inputs from mobile users. Therefore, mobile user experience can be improved and enriched.

To meet the increasing needs of mobile-based barcode applications in m-commerce, more research work and technology study are needed to understand 2D-Barcodes, required supporting technologies, standards, and applications in m-commerce mobile and services. More design and experience reports are also needed to help engineers to create effective 2D-Barcode enabled mobile applications. Although there are a number of recent publications discussing various 2D barcodes, and related technology and algorithms, there is a lack of study reports, research papers, and experience reports focusing on 2D barcode-based mobile applications in mobile-commerce, and need more design and implement reports on 2D barcode-based processing solutions.

This paper first discusses 2D barcode concepts, classifications, related technology, and major players. Then, it examines the importance and applications of 2D barcodes in m-commerce and wireless applications based on our recent study and survey on this subject. Then, the paper reports our current development effort on building a 2D-barcod processing solution for mobile applications and m-commerce systems. Although there are a number of commercial 2D-Barcode processing tools, there is a lack of published papers discussing how to create and design a 2D-Barcode processing solutions, including some experience and challenges.

This paper is structured as follows. Next section provides a brief overview of 2D barcodes, including basic concepts, classifications, major players, and required technologies. Section 3 reviews the current related work on 2D barcode application in the wireless world, discuses the importance of 2D barcodes and potential usage in m-commerce and applications. Section 4 reports a development project on building a 2D barcode processing solution as a part of barcode-enabled mobile payment system. Section 5 presents the application examples and some case study results. Finally, our conclusion remarks and future work are discussed in Section 6.

2. Understanding 2D Barcodes

The concept of barcodes appeared decades ago. Traditionally, the barcodes stored data in the form of parallel lines in different widths, and they are known as 1D barcodes, and could only encode numbers [10]. About 30 years ago, the first linear barcodes were used for railway transportation and tracking of the goods in USA. Since then, barcodes have been used almost everywhere, including manufacturing, postal, transportation, government, health care, retail business, trade show, and automotive business. Barcodes, as machine-readable representation of information in a visual format, can be easily stored, transferred, processed, and validated. A linear barcode refers a way of encoding numbers and letters in a sequence of varying width bars and spaces so that it can be read, retrieved, processed, and validated using a computer. Using barcodes provides a simple and inexpensive method of encoding text information that is easily read using electronic readers. Barcodes are used widely because barcode code technology and processing provide a fast and accurate tool to enter data without keyboard data entry. The research for storing more data in barcodes led to the development of 2D barcodes that can store large amount of data in a small area to support information distribution and detection without accessing a database. But 2D barcodes require sophisticated devices for decoding, which was a challenge until recently. Today, with the advance of the image

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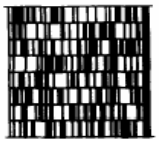
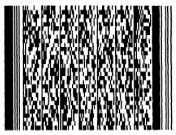
processing and multimedia capabilities of mobile devices, they can be used as portable barcode encoding and decoding devices.

The barcode symbology refers to the protocol that defines a standard for arranging the bars and spaces that comprise a particular type of barcode, such as UPC-A and EAN. It defines the technical details of a particular barcode type, including the width of bars, character set, method of encoding, checksum specifications, etc. Since the earlier forms of linear barcodes were not capable of encoding letters, 2-D barcodes were invented to meet the needs of encoding alphanumeric data, including letters, numbers, and punctuation marks. At the end of 1980s, two-dimensional (2D) barcodes appeared. With a much larger data capacity, 2D barcodes become popularly used in different areas. PDF417, Micro PDF417, and DataMatrix are typical examples. In general, there are two types of 2D barcodes: a) stacked 2D barcodes, such as Code 49 and PDF417, and b) Matrix 2D barcodes, such as Data Matrix and QR Code. Some examples of common 2D barcodes are listed below.



Code 49

QR Code



PDF417

Data Matrix

Compared with 1D barcodes which hold vary limited information data, 2D barcodes has a much larger capacity to hold more information data. As shown in table 2, a QR code can holds up to 7,089 digits, 4296 letters, and 2953 binary data. Selecting and using 2D barcodes must consider the following factors: a) the application usage, b) standard, c) implementation, d) the data you need to encode in barcodes, and d) how you wish to print the barcode. Each barcode type is a standard that defines the printed symbol and how a device such as a barcode scanner reads and decodes the printed symbol. Table 1 summarizes the capacity, features and standards of four major 2D barcodes.

Table 1 Capacity, Features, and Standards for Major 2D Barcodes

	QR Code	PDF417	DataMatrix	Maxi Code
Developer (country)	DENSO (Japan)	Symbol Technologies (USA)	RVSI Acuity CiMatrix (USA)	UPS (USA)
Numeric	7,089	2,710	3,116	138
Alphanumeric	4,296	1,850	2,355	93
Binary	2,953	1,018	1,556	
Kanji	1,817	554	778	
Main features	Large capacity Small printout size High speed scan	Large capacity	Small printout size	High speed scan
Standards	AIM International JIS ISO	AIM International ISO	AIM International ISO	AIM International ISO

Using 2D barcodes requires the following enabling technologies:

• Encoding, decoding, and scanning programs which are developed based on a selected 2D barcode symbology. They are installed and used on mobile devices or scanner devices.
• 2D barcode generation and management technologies, that support diverse 2D barcode standards.
• Mobile 2D barcode readers and scanner devices, which are cost-effective and easy to work with mobile devices.
• 2D-Barcode enabled mobile applications supporting diverse mobile applications and M-commerce services.

Recently, there is an increasing attention on the study and research of 2D barcode encoding and decoding technologies and algorithms.
T. Pavlidis et al. presents the Datamatrix symbology in [11][12][13], and point out its usage in semiconductor chips and other industrial applications due to their small size.

In 2002, H. Hahn and J. K. Joung present their implementation algorithm to decode 2D-bacode PDF-417 [8]. Adickes et al. present a test protocol for hand-held readers using the PDF417 barcode symbology [18]. They compared the performance of five hand-held readers against the other existing reader technologies, including laser scanning, linear CCD (Charge-Coupled device), and area CCCD and CMOS (Complementary Metal-Oxide Semiconductor) technology. The test result shows that the hand-held readers have the least decoding time than other readers.

E. Ohbuchi et al. [1] developed an algorithm for decoding QR code in 2004. The algorithm was used in applications where the mobile phones with a built-in camera for reading 2D barcodes. The targeted mobile phones contain an embedded host CPU, DSP camera interface and a LCD controller. G. Yu et al. [17] reports the good application result of using QR codes in identifying components in circuit boards as an effect way to improve the quality control process on a circuit board production line.

There are a number of major players for 2D barcode technology. A number of major players are summarized below.

- Intelcom (www.intelcom.ru) has been engaged in development of 2D barcode methods and software since 1999, and developed a software development kit for supporting encoding, decoding, and scanning of 2D barcodes (such as Data Matrix ECC200) on Nokia 7650/3650 mobile phones.
- Xerox is another major player in data hiding with its DataGlyphs and Embedding DigitalData. Its applications include document management, fraud prevention, inventory tracking, ID cards, parts marking or product tagging. RSVI Acuity CiMatrix Co. It is a leader in machine vision and is inventor of DataMatrix Symbology. 2D barcode tags can also be used in personal identification based on biometric technology.
- Sony Inc. has many research and experiment in use of 2D barcodes as a visual tag and way of human and computer or electric device interactions. NTT DoCoMo It is a leading Japanese company in wireless technology and mobile software applications for mobile phone uses. It has a number of research results on 2D barcode technology, and has built a 2D barcode-based application system for mobile consumers in food markets.
- TAL Technologies Inc.(http://www.taltech.com) is a major player in developing tools for 2D barcode encoding barcodes and decoding.
- AirClic (www.airclic.com) It provides tiny barcode readers, which can be attached to mobile phones.

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Figure 1: Interactions between a 2D barcode and a Mobile phone (Source:www.quickmark.com.tw)

3. 2D Barcode Applications in M-Commerce

As pointed out by H. Kato and K. T. Tan [2], 2D barcodes were designed to carry significantly more data than its ID counterpart. Mobile phones have evolved from just a mobile voice communication device to what is now a mobile multimedia computing platform. Recent technology development and integration of these two make more interesting and diverse applications of 2D barcodes in mobile application systems and m-commerce services. Figure 1 shows different interactions between a 2D barcode and a mobile phone. In M-Commerce systems, 2D barcodes can be used to support pre-sale, buy-and-sell, post-sale activities for mobile commerce transactions. For example, 2D barcodes can be used as advertisements, coupons, or promotion materials that can be captured and decoded by the user with mobile devices. Moreover, 2D barcodes enable mobile devices to become a point of sale device that reads the barcode and facilitates payment transactions. After a payment transaction, 2D barcodes can be used by customers as a receipt or proof of purchase to gain access to the purchased goods and services with their mobile phones.

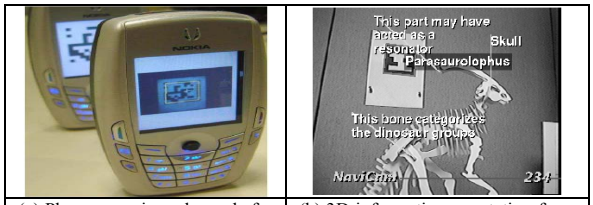
With the fast increase of the number of wireless users, more M-commerce application systems and services are needed. However, one of the critical issues in building M-commerce systems is mobile data entry. For example, when a mobile customer wants to access a wireless internet site (http://yahoo.com) using a mobile phone, she must enter the address through 33 clicks using the device keyboards. Therefore, the major challenge in M-commerce is where to find an effective interface technology to support the simple and efficient interactions between mobile customers and M-commerce systems without mobile keyboard data entry. Barcodes provide a simple and effective solution to cope with this issue due to their advantages over linear barcodes in data capacity and visual representation size. For instance, using the shotcode solution given in http://www.shotcode.com/, mobile customers only needs two clicks to enter the URL http://yahoo.com.

Until recently, people are gradually realized the importance of 2D barcode and its great application value in M-Commerce because of the followings:

• 2D barcodes provide a new effective input channel for mobile customers carrying mobile devices with inbuilt cameras.
• 2D barcode is becoming a popular approach to present semantic mobile data with standard formats.
• 2D barcodes support a new interactive and efficient approach between mobile customers and wireless application systems.
• 2D barcode technology can be and are being used in diverse applications in mobile commerce.

As the fast advance of 2D barcode enabling technology, people have found its great value and diverse applications in M-commerce.

- *Wireless advertising and marketing* – 2D barcode becomes one of best cost-effective advertising and marketing tool for advertisers and manufactures. Using a mobile camera phone, a customer can easily input a 2D barcode on a product advertisement (posted everyone), found more product information from the barcode. When the customer likes the product, only a very few clicks can lead to a trading transaction with the backbone M-commerce application system. Clear mobile 2D barcode ads on mobile devices are transaction-oriented ads, which allow mobile customers to purchase products as long as they see their ads at anywhere and anytime.
- *Wireless trading (pre-sale/sale-and-buy/ post-sale)* – Using 2D Barcodes on products and goods, merchants and manufactures allow mobile customers to find more detailed product information. For example, NTT DoCoMo, in Japan, is developing a system using 2D barcodes for food consumers. Using mobile camera phones, consumers can easily input a 2D barcode of a product by scanning product barcodes in the store, and found more detailed information about each product, including producers, harvest date, shipping date, and agricultural chemicals in each found. In addition, 2D barcodes are also very useful in post-sale, including product tracking, shipping, and delivery. Furthermore, they can be used as very effective tool to prevent the frauds in luxury goods, such as paintings. Johnston and Yap in [16] considers the feasibility of transmitting EDI shipping information using PDF417 2D barcodes in terms of organization, technical and practical feasibilities. Their results indicate that there is no risk using 2D barcodes in EDI-based applications.



(a) Phone scanning a barcode for authentication (Source: http://www.ece.cmu.edu/~jmmccune/papers/mccunej_believing.pdf)

(b) 3D information annotation from a view of a NaviCam in a museum (Source:http://portal.acm.org/citation.cfm?id=354667&dl=ACM&coll=GUIDE)

Figure 2 Some Mobile Applications of 2D Barcodes

- *Product information tracking and checking* for mobile users. For example, K. Seino at al. [15] describes an application that can be used to trace the fishery products using QR codes. Another example is CyberCodes, developed by Sony Computer Science Lab. [5]. This technology used the embedded cameras in the mobile devices for decoding the 2D barcode tags - CyberCodes. This technology can be used for indoor navigation or indoor guidance. For instance, CyberCode tags can be printed on the items inside a museum. Visitors can retrieve the relating information by scanning the CyberCode tages on the items. An exhibition in Tokyo used CyberCode tages for works of architecture Neil Denari in 1996 [3]. Figure 2 (b) shows an example.

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- *Mobile security*– As we know most security solutions are developed based on some kinds of encoding and decoding cryptographic algorithms, clearly it is easy to use a 2D barcode technology to embed diverse security data (or code) into a 2D barcode by an encoding and a decoding process. One good example is the system, known as Seeing-Is-Believing, developed by Carnegie Mellon University [6]. As shown in Figure 2(a), the system utilizes 2D barcodes and camera-phones to implement a visual channel for authentication and demonstrative identification of devices. The authors of the paper apply this visual channel to several problems in computer security, including authenticated key exchange between devices that share no prior context, establishment of a trusted path for configuration of a TCG-compliant computing platform, and secure device configuration in the context of a smart home.

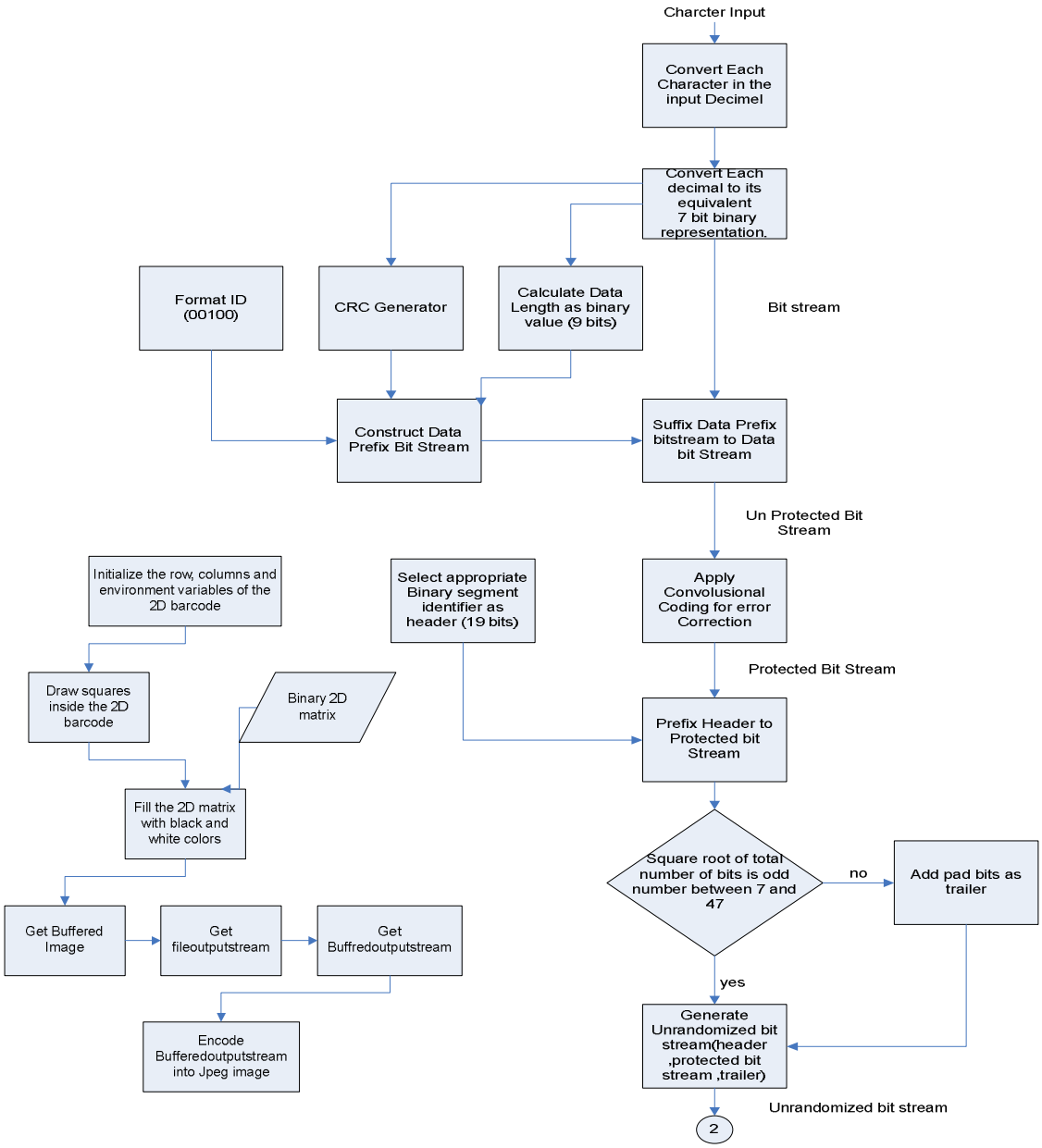

Figure 3 Data Encoding Sequence

- *Mobile customer and product verification* - Using 2D barcodes merchants (or delivery man) can easily perform various verifications using mobile scanner devices (or mobile devices) to scan 2D barcodes on a movie (or train/flight/sport) ticket, a coupon, a good, or an invoice [1][7][18][14]. Consumers also are able to carry out product verification by accessing the 2D barcode of a

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product/package to check its detailed product information, track its shipping and transaction history.

- *Wireless payment* – Most current electronic payment systems are account-based payment systems (using ATM/credit/cash cards and e-checks), micro-payment system based on digital cashes, and e-wallets. We believe that 2D-barcode technology provides a new way to develop mobile e-card based payment systems that allow customers to make payments using mobile phones with 2D barcode technology. For instance, 2D barcodes can be used as to present different digital mobile cards. They can be stored in a wallet of mobile devices, and used to make diverse type wireless payment transactions at anywhere and anytime. The typical mobile payment transactions are: a) peer-to-peer transactions between a buyer and a seller, and b) point-of-sale transactions between a mobile device and a terminal device, such as a vending machine, a casher's payment station, and a TAXI driver's payment device. With 2D barcodes, mobile payment solutions should be able to provide more secure, efficient, and easy to use payment solutions to mobile customers.

4. A 2D-Barcode Processing Solution

Since 2006 we have started a new project to build 2D Barcode-enabled mobile payment system to enhance our existing P2P-Paid system [19]. To support this project, we need a 2D barcode processing solution to perform encoding and decoding process for a given 2D barcodes. Based on our recent survey, we found 2D barcode Datamatrix symbology is a very popular technology and standard used in many applications. Hence, we used the standard defined by the Information Technology-International Symbology Specification-Data Matrix (ISO/IEC 16022) [9] and developed a 2D barcode processing solution.

This solution includes the following parts:

- A User Interface, which supports users to use it as a tool to perform decoding and encoding of any text strings, and monitor and display the corresponding results.
- A User Interface API, which allows developers to use it as a reusable component for 2D barcode processing in any application.
- Encoding module, which includes two parts: ***data encoder*** and b) *image generator*. *Data encoder* performs data encoding functions. They are: a) generating encoded data in bit stream format, b) adding unprotected bit stream, c) calculating a header and a trailer, and appending them to the unprotected bit stream to produce protected bit stream, d) pattern randomization for extended security, and e) module placement to form the matrix using a special placement algorithm. Figure 3 shows the corresponding function scenario sequence. ***Image generator*** includes the functions to create the 2D barcode image. Figure 5 displays the relating function sequence. We used the JPEG image format in the implementation.
- Decoding module, which provides the decoding process by the following two parts: a) *image decoder*, and b) *data decoder*. *Image decoder* recovers the binary matrix from the given 2D barcode image. Figure 4 shows the corresponding scenario in the processing solution. *Data decoder* further processes the matrix and recovers the original data string. Figure 6 shows the relating processing sequence.

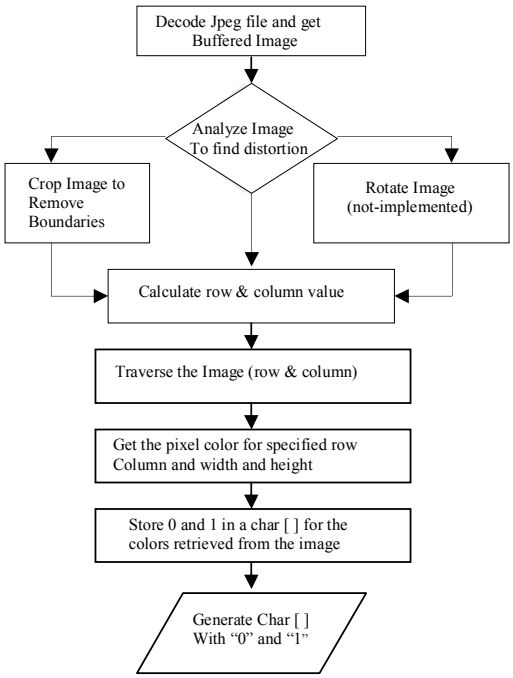

Figure 4 Image Decoding Sequence

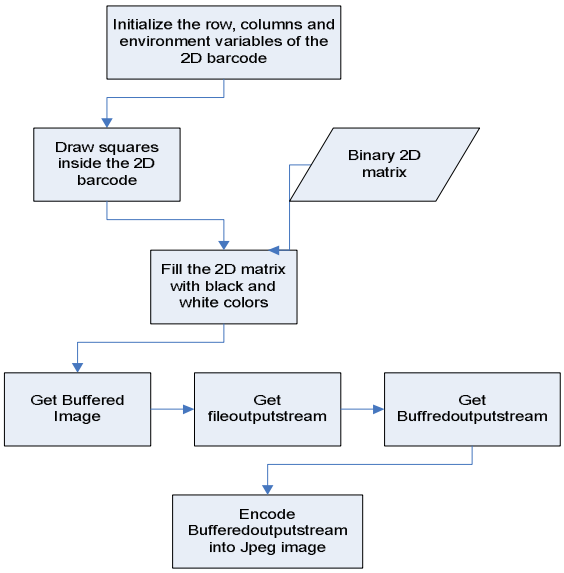

Figure 5 Image Decoding Sequence

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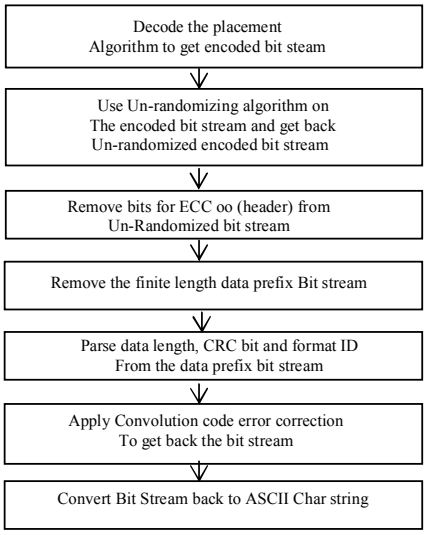

Figure 6 Data Decoding Sequence

5. Application Examples and Case Study

The developed solution has been tested using various examples. Table 2 presents the encoded 2D Datamatrix barcodes for the given text string examples. They include: a) credit card information, b) product information, c) security key information, and d) user information. Table 3 shows two decoding examples.

Table 2 Encoding Examples

Credit Card Information	**Corresponding 2D-Bar Code**
Customer Name: Lekshmi Prakash Credit Card Num: 4508123456787654 Card Type: American Express Exp Date: 02/07/2008	
Product Information	**Corresponding 2D-Bar Code**
Product Name: Dell Inspiron *Product Id:* *KEW32 GT56U OP789 Manufacture*	

Security Information	**Corresponding 2D-Bar Code**
Public Key: *L@#%?HKITIOP* *Session Id: 89756*	
User Information	**Corresponding 2D-Bar Code**
Customer Name: Lekshmi Prakash Address: 460 Oak Grove Dr, Santa Clara, CA, 94564 Customer Id: LRP234	

Table 3 presents two decoding examples for the given 2D Datamatrix Barcodes.

Table 3 Decoding Examples

Decoding Sample #1	**Given 2D-Bar Code**
Decoded String: *Product Name: Dell Inspiron* *Product Id: KEW32 GT56U OP789* *Manufacture Name: Dell*	
Decoding Sample #2	**Given 2D-Bar Code**
DECODED STRING: *RA*	

To facilitate the needs of a barcode enabled mobile payment system, we enhanced our encoding and decoding processing solution for 2D Datamatrix barcodes by providing a multiple information encoding and decoding feature. With this feature, a user can easily perform the following two tasks:

- Encode multiple data information into one Datamatrix code
- Decode one (or more) selected data information from a given multi-segment Datamatrix code.

Since a typical payment transaction record must includes four types of data: a) customer information, b) product information, c) payment information, and d) security information. Hence, we tested this feature with a simple payment transaction data. The encoding result and selected decoded result is shown Table 4.

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A case study has been done to evaluate the design and implementation of this processing solution in terms of performance and string size. Figure 7 shows the performance analysis of this implemented solution based on given string sizes. It is interesting to notice that the current version of encoding component has a fairly good performance for various lengths of encoding text strings. However, the decoding component has some performance problem to deal with short text strings. But it performs fine for text strings with over 90 characters. To examine the performance details and relating issues, we have done some performance analysis for major functions (or methods). A sample of detailed analysis results are presented in Figure 8.

Table 4 Encoding and decoding samples of a multi-segment Datamatrix code

Multi-segment Data Information:

String 1: Customer information
Customer Name: Lekshmi Prakash

String 2: Payment information
Credit Card Num: 4508123456787654
Card Type: American Express Exp Date: 02/07/2008

String 3: Product information
Product Name: Dell Inspiring
Product Id: KEW32 GT56U OP789
Manufacture Name: Dell

String 4: Security information
Public Key: L@#%?HKITIOP
Session Id: 89756

Encoded Datamatrix 2D Barcode:

Selected Decoded Data information (Segment #3):

String 3: Product information
Product Name: Dell Inspiring
Product Id: KEW32 GT56U OP789
Manufacture Name: Dell

6. Conclusion and Future Work

This paper discusses the importance of 2D barcodes and their usage and impacts in mobile commerce and wireless applications. It reviews the current innovative initiatives in 2D barcode enabled mobile application systems. Moreover, the paper reports a project in building a 2D barcode processing solution for mobile payment systems, including its design and implementation, as well as application examples and case study result.

The future work of this research includes two areas: a) to enhance the existing 2D barcode solution to deal with non-perfect 2D barcode images, and b) building a 2D barcode enabled mobile payment system.

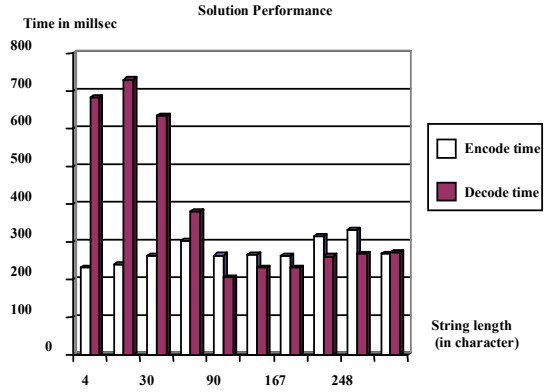

Figure 7 Performance Analysis Results

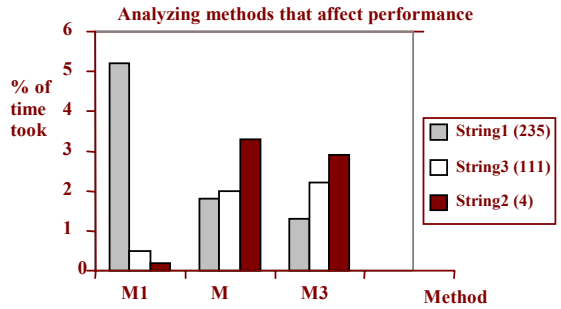

Figure 8 Performance Analysis on Different Processing Methods

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