Development and popularization of QR code

—Code development pursuing reading performance and market forming by open strategy—

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Due to advances in information technology, we predicted the widespread decline of barcodes as an information tool. Instead, we developed QR codes, to replace barcodes, using image recognition techniques. We have made innovation to QR codes to meet market needs. To popularize QR codes, we made QR codes available to the public and have formed a market in cooperation with many companies. As a result, QR codes have been used to improve work efficiency and convenience. QR codes are currently available as a communication tool for people all over the world.

Keywords : Two-dimensional code, barcode, image recognition techniques, error correction code, open and closed strategy

1 Introduction

The QR code[Term 1] was developed in 1994 in response to the demands of diversification and increased information volume necessary in the advanced information age, as well as to the demand for high-density printing that satisfied the requirement of individual item management at the component level at manufacturing sites. QR codes are matrix type two-dimensional codes in which information is expressed by arranging white and black cells on a lattice much like a checkerboard. Barcodes that are widely diffused now express information by thickness of the bar width. While barcodes can only express information in one-dimension, QR codes allow 2D expression of information that enables information to be written at high volume and high density. The QR code has diffused as a code that can be used in the next-generation information age, along with the advancement of computers and network. To diffuse the QR code widely, it was declared public domain (a code that can be used freely with no patent claims). As a result, it is now used by societies and citizens around the world, in various services in linkage with smartphones.

24 years has passed since the birth of the QR code, but new ways of using it are devised every day. It continues to spread around the world.

2 Background of development

About 40 years ago, Denso Corporation proposed an integrated production system for products and information by introducing barcodes to Toyota's kanban method. "Kanban" is a tool to realize the just-in-time production method that is the basic philosophy of Toyota. It is a specification sheet that is attached to the components and travels everywhere with them. As production volume increased, more invoices had to be processed, and more mistakes occurred as data input was done manually on the computer. Therefore, barcodes were introduced to the "kanban" along with the reader to read the codes to achieve automatic input to the computers. Denso realized the importance of information, was convinced that the information age would arrive with the diffusion of computers in the future, and developed several information input devices for computers. It started on the development of the QR code in 1992. At the time, barcodes were widely used as an accurate, fast, and low-cost input method in printed form.[1] However, the age in which anything could be sold after being manufactured ended with the burst of the economic bubble, and manufacturing trends shifted from mass production to "multiple product low volume" production.

The manufacturers started to conduct finely-tuned production control, and with the increase of information volume handled, about 10 different barcodes had to be read for management control at manufacturing plants. This slowed down the production efficiency, fatigued the workers, and generated many complaints. Also, after the collapse of the bubble economy, many companies pursued high quality as a differentiation point of their products. Since they wished to maintain control at the component level, there were increased demands for a code that could be printed on micro-sized components such as IC.[2] With the coming of the information age, there was an electronic data interchange (EDI) concept

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that was promoted among private companies by the Ministry of International Trade and Industry (currently, Ministry of Economy, Trade, and Industry). There was a demand for a code that could hold large-volume data for handling kanji on industrial standard invoices. Moreover, from the perspective of environmental issues such as forest destruction, there was a demand for a code that allowed high-density printing that reduced the amount of paper use. It was thought that in the information age that would advance in the future, more information would be handled, and the barcode, which was widely used as an information input method at the time, inevitably would hit its limit. Therefore, the QR code was developed as a next-generation code that could respond to the requirements of an advanced information age.

3 Scenario for development and diffusion

3.1 Development concept and development goals

No matter how excellent a code is developed, a company will not be successful unless the code is widely used in society. Therefore, the QR code was developed according to the following development concepts with the goal of diffusing the code throughout the world.

(1) To provide a code that can respond to the requirements of advanced information age and can evolve according to the changes of the ongoing trends.
(2) To develop a code that can be easily read (that has high readability performance) from the viewpoint of the users.
(3) To create and practically realize an environment in which users can use this code freely and securely.

As mentioned in the background of development, the social demand was for a code that allowed high-density printing of high-volume data, but considering the significant progress of computers and network in the future, a prediction of social demands in 10 years from now was difficult. Therefore, we decided to develop a code within the range we could predict, and to alter or evolve the QR code according to the changing social demands. In terms of social demands, it is often the case that only the demands from people who make the system and application come to the surface. However, for wide-ranging diffusion, it is necessary to provide devices and services that people on site who will actually use them will want to use. Therefore, we decided to develop a code from the perspective of people who would actually use the QR code. Unless the QR code developed can be read, it is totally nonproductive and useless for the user. Therefore, we considered the reading performance of the QR code to be the utmost important point. Also, for the new code to be used, it is essential to provide an environment with sufficient infrastructure and security. A secure environment means that there will be assurance of long-term secure usability of the QR code and no possibility of retraction due to business slump caused by a monopoly by one company, nor cessation of service due to patent violation by another company or demand for license fee payment.

As a scenario for developing the QR code that will be used widely in society, as shown in Fig. 1, a four phase plan was created for market demand, technology/product development, diffusion activity, and market activation.

3.2 Development goal and scenario

In the demand survey, since we thought that the opinions and

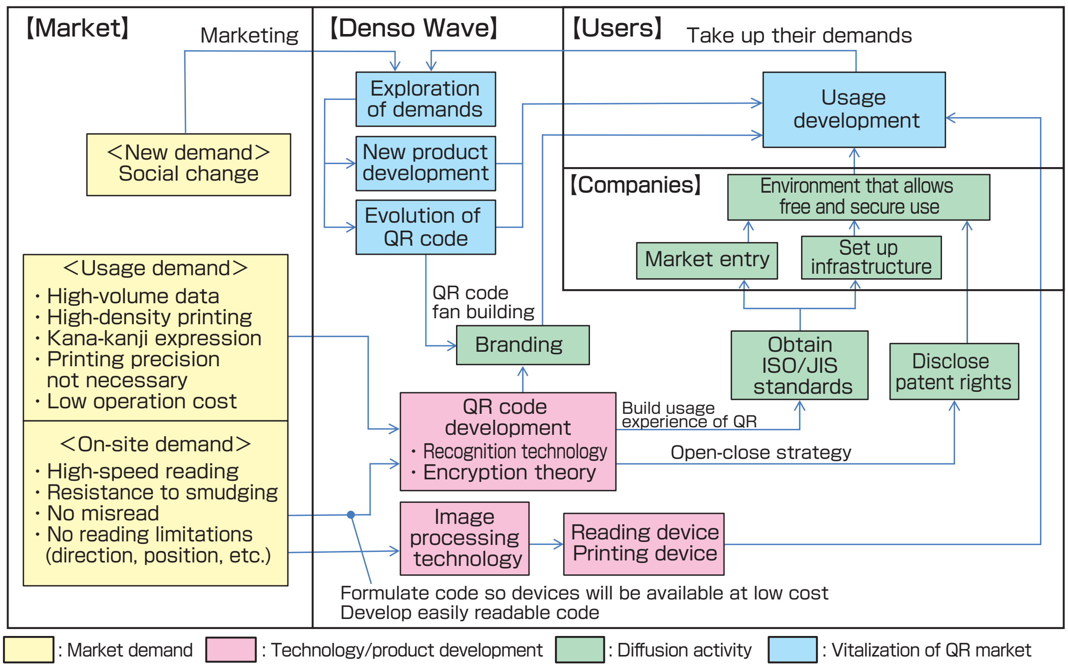

Fig. 1 Scenario for development and diffusion of QR code

Table 1. Development goal for QR code

Item	Goal values	Barcode
Data capacity	Alphanumeric characters: 4,000 characters or more Kanji characters: 1,600 characters or more	About 30 characters
Information type	Alphanumeric, kanji Binary data	Cannot handle kanji
Reading direction	No limit	Limited
Reading speed	30 ms (100 digits)	About 30 ms (20 digits)
Error correcting capability	30 % of surface area restorable	None
Misreading rate	10^{-9} or less	About 10^{-6}

requests from the people who were actually using barcodes on site were the key, rather than surveying the social demands, we primarily gathered on-site voices. As a result, the majority were requests for improving the barcode reading performance and the operability of the barcode reader. The following items were particularly most frequently requested.

(1) Enable quick reading of much information (multiple barcodes).
(2) Enable reading of smudged or damaged barcodes.
(3) Put in measures to prevent misreading .
(4) Since barcodes have limited orientation in reading, make it easier to set the correct orientation so it can be read by reading devices.

To improve the readability performance and operability, the general method is to realize these on the reading device using image processing technology, but we decided to work on the code itself to develop an easily readable code. The reason was because while more processing time is needed when image processing technology is used, it was possible to differentiate from other codes by adding characteristics to the code. Moreover, it would be more acceptable in the market if the code could be read by low-cost reading devices with low processing ability, and we thought this was important in wide practical use of the QR code. Therefore, we set the development goals as shown in Table 1 based on the social demands and on-site comments. The specific goal values were determined based on the barcode.

In the development phase, emphasis was placed on code development that allowed high-speed and accurate reading of large-volume data in any environment. 2D codes are roughly divided into two types. One is the stacking barcode in which several barcodes are placed on top of each other vertically. The other is the matrix code in which white and black are arranged in a lattice. The stacking barcode has the advantage that it has the same reading principle as the conventional barcode, has relatively quick reading time, and reading devices can be shared with the barcode. However, similar to the barcode, high-density printing is not possible, so large-volume data cannot be handled, and the orientation in which it can be read is limited. The matrix code is a method in which the center of the lattice is identified as white or black, and therefore has the advantage of not requiring printing precision, and this allows high-density printing and large-volume data. However, more time is needed for reading since the structure is more complex than the barcode.[3] We selected the matrix code because there was expansivity in large-volume data and high-density printing, considering the information age that will become more advanced in the future. Denso had about 40 years of experience in product development of optical information readers for barcodes and OCR, and it set out to develop a matrix code that can be easily read, utilizing image recognition technology obtained from its experience.

For high-speed reading, a majority of the reading time for the matrix code is spent on the process of extracting the code from the image. High-speed reading is enabled by placing a characteristic symbol suitable for code extraction within the code. We achieved reading time of about 30 ms that is similar to the barcode but at five times the information volume of the barcode.

For reading of smudged codes, we adopted Reed-Solomon coding that is suitable for burst error such as smudging and has high correction efficiency. This enabled reading even if 30 % of the code is soiled or damaged. Also, Reed-Solomon coding allows high degree of design freedom, and by using part of the added redundant data for error detection, the rate of reading erroneous data is kept to 10^{-9} or less.[4]

For operability, a symbol to correct the distortion was placed in the code to ensure stable reading to compensate for codes that are printed on curves or for optical distortion that occurs by the angle of the reader and code.

3.3 Scenario for diffusion

No matter how excellent a code is developed, it will not diffuse unless infrastructure is in place and anyone can use it freely and securely. Infrastructure building could not be done by Denso alone, and if time was required for diffusion, other 2D codes and new technology might have taken over. Therefore, in the diffusion phase, we thought the key would be to form a QR market early by urging many companies to participate in the QR market and to cooperate in infrastructure building. To do so, it was necessary to obtain industrial standards and international standards, but those required much effort, and much time was needed to obtain an ISO standard. Therefore, to ease the obtainment of such standards, priority was placed on the diffusion of use in automobile, electric/electronic, and distribution industries that engaged in global business, and the ISO standard was obtained in six years after the birth of the QR code.

In building an environment in which anyone can use the code freely and securely, we utilized the patent for the QR code as follows. We employed a policy in which patent rights were disclosed to QR code users, while copies and unauthorized use of QR codes were eliminated from the market by claiming patent rights. Possession of patent rights proved that we would not be sued for any patent violation, thus providing an environment in which the users could use the code freely and securely.

In the market activation phase, we thought the key was the development of usages that generated values for the users. If wider usage development could be done, the QR market would also expand. Therefore, usage development in fields where we lacked experience was referred to the power of the users. To do so, the QR code had to be attractive to the users. Therefore, we embarked on brand building for the QR code with an image of high performance, high quality, and security. New usage development was undertaken according to changes in society through technological progress, and the QR code evolved according to new demands that could not be handled by old technology. This prevented the QR code from becoming obsolete, and its brand power increased as a code that always had an edge. Then, the QR code diffused explosively.

3.4 Scenario for commercialization

Denso’s QR business was conducted by an open-close strategy considering the strength and weaknesses of the company. To get other companies to cooperate in market formation, the QR code was made open after standardization. On the other hand, our profits were gained by providing familiar reading devices and services to the QR market, and the QR reading devices remained closed. The image recognition technology that was the core of code reading was kept as corporate secret without applying for a patent, while patents were obtained for other reading devices that were licensed to others. With the advantages of reading performance and quality obtained in the field of automobile manufacturing, we set the solution business as the pillar of our business profit.

We achieved business growth by differentiating from the competitors in brand power, as the manufacturer that developed the QR code based on image recognition technology and know-how in the barcode business. Also, by supporting the users’ usage development by utilizing technologies and know-how that evolve the QR code, we were able to capture market demands quickly, and that put us in the lead against our competitors.[5]

4 Outline of QR code

The name of the QR code comes from “quick response” that represents high-speed reading that is its greatest characteristic. The QR code was developed with emphasis on ease of use in various applications. Other than large-volume and high-density recording that are the characteristic of 2D codes, it also maximizes the reading performance that allows high-speed and accurate reading of codes even with smudges, damage, or distortion.

4.1 Structure of QR code

As shown in Fig. 2, the QR code is composed of a data region (shown in grey) and function patterns including a finder pattern, an alignment pattern, and a timing pattern.

4.1.1 Finder pattern

A finder pattern is a symbol for detecting the position of the QR code. It is a symbol composed of unique patterns with bilateral symmetry (black-white ratio 1:1:3:1:1) that is uncommon in printed materials, so it can be detected easily, and this unique pattern appears in all 360º directions. By setting finder patterns in three corners, the position, size, and inclination can be immediately detected even if there are letters or figures printed around the code.[6][7]

4.1.2 Alignment pattern

An alignment pattern is for correcting distortion of the code. It is particularly effective in correcting nonlinear distortion. Distortion of codes is corrected by calculating the central coordinates of the alignment pattern. The alignment pattern has a structure that allows accurate detection of the central coordinates by placing a black isolated cell in the center, and this enables highly precise correction. This then allows accurate reading of distorted codes.[6][7]

4.1.3 Timing pattern

This pattern supports accurate calculation of the central

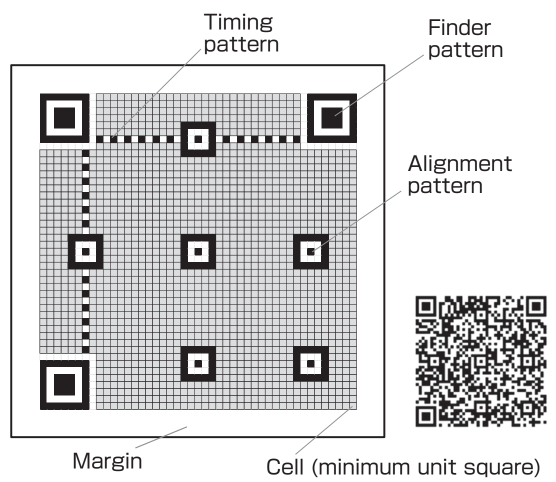

Fig. 2 Structure of QR code

Table 2. Outline of specifications for QR code

Item	Specifications	
Size of code	Minimum 21 x 21 cells Maximum 177 x 177 cells (4 cell intervals) ☆ In cases cell size is 0.25 mm ・Numerals 40 digits: 5.25 mm square ・Numerals 7,089 digits: 44.25 mm square	
Type and volume of information	Numeral	Maximum 7,089 characters
	Alphanumeric	Maximum 4,296 characters
	Binary	Maximum 2,953 characters
	Kanji*	Maximum 1,817 characters
Data restoration function	Restoration is possible even if about 7 %, 15 %, 25 %, or 30 % of code surface area are damaged (can be selected from 4 levels)	
Linkage function	Linkage of up to 16 codes is possible (Maximum about 46 Kbyte storage) ☆Example of six links 1/6 2/6 3/6 4/6 5/6 6/6	

＊In QR code, Level 1 and 2 JIS Kanji characters are compressed to 13 bits

coordinates of each data cell. The white and black patterns are placed alternately in two places vertically and horizontally between the finder patterns. Even if the code is distorted partially or cell pitch gaps occur due to poor printing, this allows accurate reading of central coordinates of the data cell.[6][7]

4.1.4 Data range

QR code data are arranged in the data region shown in gray. The data are binarized in ‘0’ and ‘1’ according to rules. The ‘0’ is converted to white cells, and ‘1’ into black cells. The data region contains Reed-Solomon codes that realize error correction.[6][7]

4.2 Specification of QR code

QR codes increase in size according to the stored volume of information, and the sizes range from 21 × 21 to a maximum of 177 × 177 cells, in intervals of 4 cells. It is possible to link 16 QR codes, and a maximum of about 46 kilobytes of data can be stored. Table 2 shows the outline of the specifications of the QR code.

5 Characteristics of QR code

Here, the characteristics of the QR code will be explained including particularly excellent high-speed reading, and the property that allows accurate reading even with smudging and damage.

5.1 All-direction high-speed readability

Normally, reading of 2D codes is done using a 2D image sensor. Image data read with a 2D image sensor is decompressed on the memory, analyzed in detail with software, and only the code is extracted. The position, size, and incline of the code are detected, and decoding is done by calculating the central coordinate of each cell. In general matrix codes, the captured image is searched with a software, and when a black part is detected, peripheral detection is conducted to determine whether it is a code, and if it is not a code, it moves to the next black part. Therefore, a majority of the time required for reading is spent on processing. Particularly, if there are noises such as patterns that look like letters in the background, the information volume that must be processed increases to about 800 times the amount of the barcode. This requires an extremely long time for processing, and reading performance seems inferior to the barcode. With the QR code, the finder pattern is placed in three corners to detect code location, and this enables high-speed scanning in all 360º directions. Figure 3 compares processing of a general matrix code and the QR code.

With the finder pattern of the QR code, the black-to-white ratio of the scan line that passes through the center of the finder pattern is 1:1:3:1:1 from all 360º directions, as shown in Fig. 4. With this unique ratio, it was found it had an extremely low chance of occurrence after surveying the black-white ratio that comprised the letters and figures. This

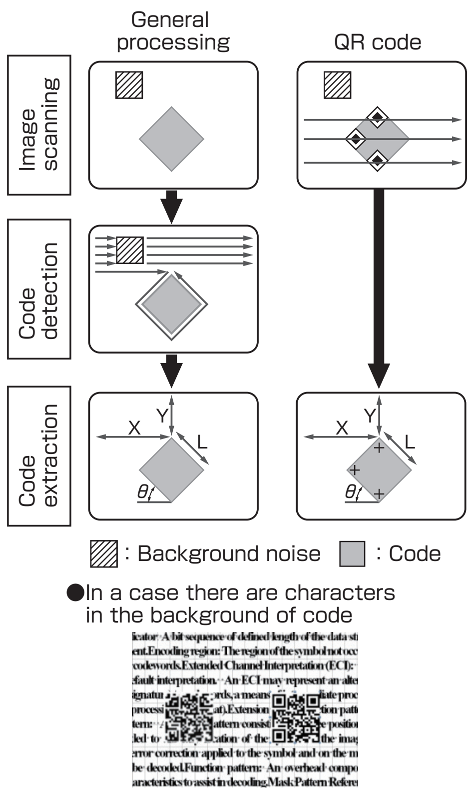

Fig. 3 Detection processes of position and shape of code

ratio can be detected when the image is output from the 2D image sensor using raster scanning, and therefore the position of the QR code can be determined from an image including letters and figures, without searching the memory. From the positional relationship of the three finder patterns, the size and inclination of the code can be determined, and the shape of the code can be detected instantly.[8] Therefore, by detecting the finder pattern, to search for boundaries and periphery of the code symbol among scanned images becomes unnecessary, and the reading speed can be increased by about 50 times compared to processing a general matrix code.[7][9] This allows reading information volume five times the barcode at the same speed of 30 ms of the barcode, even using a versatile CPU (32 bit RISC CPU: 18 MIPS). The hardware for detection of finder patterns was easily created, and this allowed the shape of QR codes to be detected at the same time as image scanning. This enables image scanning at real-time for QR codes that are moving at high speed.

5.2 Resilience against smudges and damage

For the QR code, four levels were set in which recovery became possible even if 7 %, 15 %, 25 %, or 30 % of the code surface area are damaged, by employing Reed-Solomon coding that is the error correction code. In a clean environment such as an office, 7 % can be selected whereas 30 % can be selected in poor environments like a plant, and the choice can be made according to the environment or application.[6] It is designed so the error correction rate will be 10^{-9} or less in all code variations. To increase the scanning performance, measures are taken to arrange the black-white cells in a good balance, without unevenness. This process is called the mask process. As shown in Fig. 5, when placing the stored data in the data region after coding them, the EX-OR operation (WHITE if both cells are black or both are white, BLACK if not) is conducted between the cells for the data region and the cell for a mask pattern that has been prepared beforehand (template), and the pattern in which the black-white cells are most well balanced is used as the QR code.[10] Arranging the black-white cells in a good balance allows reading of QR codes with particularly poor uneven luminance. In a general binary-coded process, a luminance histogram of the image is taken, and using the luminance T1 of the valley part as a threshold value, the luminance T1 or more is set as white cells while luminance of less than T1 is set as black cells. When this is done, the left part of a QR code tends to have more white cells while there will be more black cells on the right part, and it can be understood that the binary threshold value T1 is bad. To remedy this, valleys T2 and T3 are set in places with lower and higher luminance than threshold T1, and if the regions with more white cells are processed as threshold T3 and regions with more black cells as threshold T2, it is possible to accurately determine the black-white of the cells. This allows scanning of poor quality QR codes.

6 Evolution of QR code

Since the birth of the QR code, new QR codes were developed and advanced in the four categories, “miniaturization,” “increased volume,” “design,” and “security,” considering the creation of user value by capturing the changes in social demand. Figure 6 shows the history of the progress of the QR code.

With the arrival of the QR code, there were increased demands for managing small products and micro-size components such as electronic components, pharmaceuticals, and precious metals that could not be managed with barcodes. Therefore, a micro QR code was developed in 1998, and this allowed data of about 20 alphanumeric characters that included product codes and serial numbers to be printed in a 1 mm square, while maintaining the reading performance of the QR code. Moreover, responding to the demand for management of small, cylindrical products and test tubes with tight curves from the medical field and manufacturing plants, iQR codes that support rectangular shapes with increased data efficiency was developed in 2008. When Japanese companies went to Asia such as China

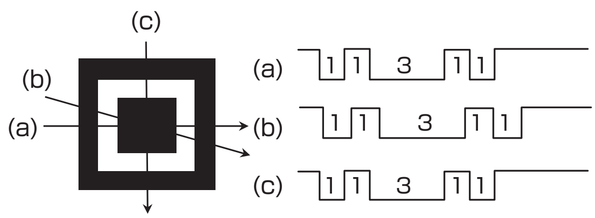

Fig. 4 Characteristics of finder pattern

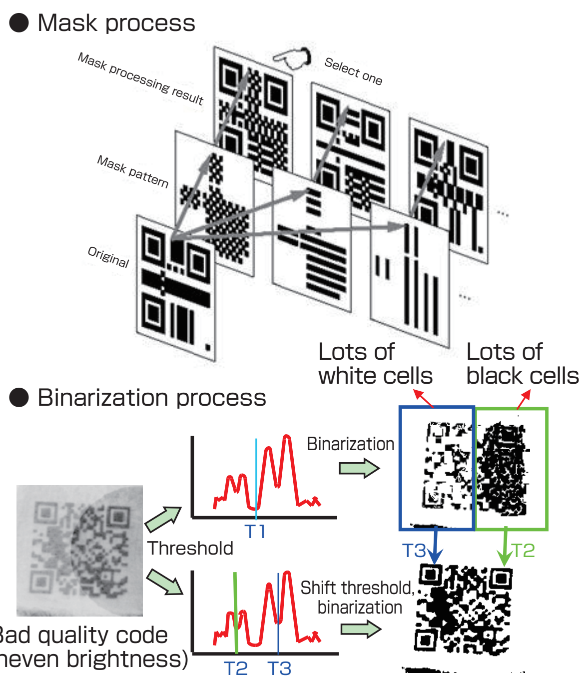

Fig. 5 Effect of mask processing

in 2000, there were demands for efficient handling of non-Japanese kanji and hangul, that are non-alphanumeric, multi-byte characters. Therefore, QR codes that incorporated Asian languages including kanji of China and Taiwan and hangul of Korea were developed in 2001. National standards of Asian countries were obtained.

For security, due to the diffusion of mobile phones with functions that enabled QR code reading since 2004, anyone could read QR codes, and there was the issue that QR codes that were primarily used by companies for invoice control could be easily read by customers. To solve this issue, SQRC was developed in 2007. The greatest characteristic of SQRC was the two-layer structure of an open information region and a closed information region. The open information region can be read by all scanning devices including mobile phones, while the closed region has encrypted information that can be read only by scanning devices that have matching encryption keys and SQRC recognition software for decoding. With this SQRC encryption function, the demand for use in tickets increased as a new usage, as the data could not be altered. However, since it could be easily duplicated with copiers, it could not be used in expensive tickets. Therefore, a copy-guarded QR code in which the printed SQRC was covered with ink that passed special light and could not be duplicated or altered was developed in 2011. The technology in which luminescent ink shines when irradiated with black light (UV) is known, but copy-guarded QR codes are invisible to the naked eye even when irradiated with light of a special wavelength, and one cannot tell where the SQRC is, and that increases the security.

In terms of design, social networks dramatically diffused since 2005, and many people started to create QR codes of companies or personal addresses. Against such a background, there was increased demand for one's original QR code, and the companies demanded QR codes that were unique looking that caught people's attention and made them want to access company websites. Therefore, frame QR was developed in 2014. Frame QR is a code with reading performance of the original QR code by setting a special canvas that hold an image or logo in the center of the code.[11] This increases the design property, but also increases convenience since images or illustrations indicate the kind of information sites one can expect to access. The QR market expanded with the evolution of the QR code that responded to social demands.

7 Spread of QR code

Figure 7 shows the spread of the QR code. In the 1990s, since it was used mainly in the fields of manufacturing and distribution, QR codes were not visible to the general public.

In 2000, the ISO standard was set, and QR codes were used for betting tickets, vehicle inspection stickers, and airline tickets. In 2002, when QR codes became readable with mobile phones, they were used for accessing websites, and they appeared in newspapers, magazines, and posters, and by this time, everyone knew what the QR codes were.[12] The use in public, administration, and distribution increased around that time, and the QR market suddenly expanded.

Since 2005, social networks spread widely, and the QR code was used as a communication tool to connect personal

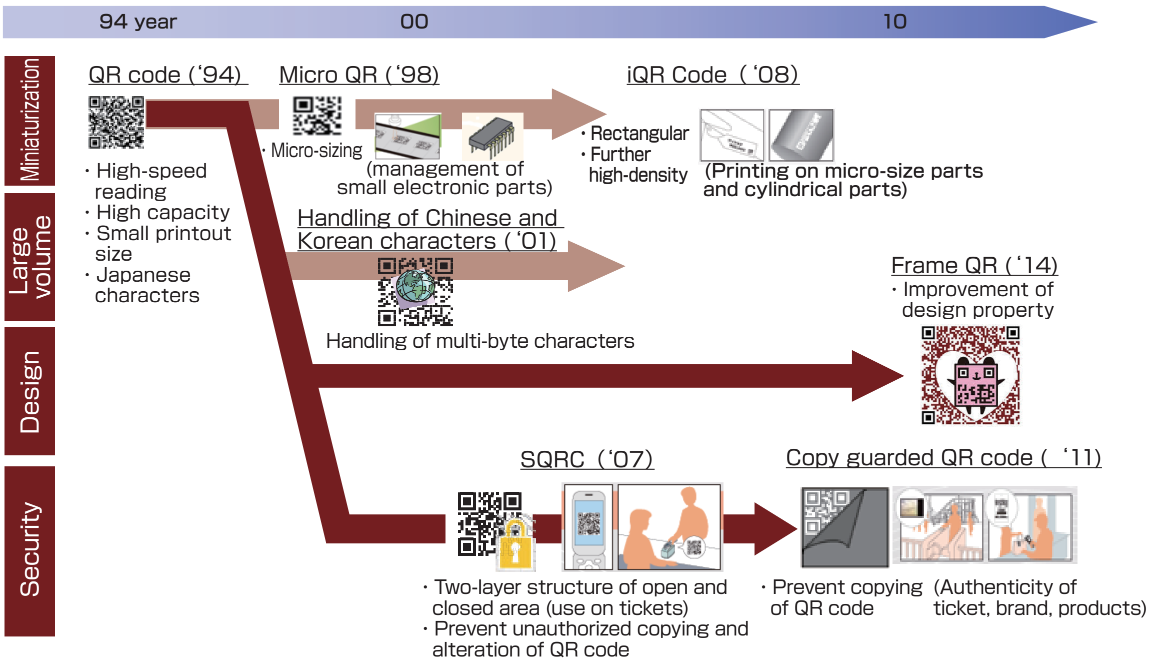

Fig. 6 Evolution of QR code

information, and a market was created in general consumer fields such as games and sales promotion. Moreover, since 2010, people throughout the world started to use QR codes with the diffusion of smartphones, and the market expanded explosively.

8 Conclusion

As the QR code diffuses widely, many people say Denso should have monopolized it. In fact, there is no way of knowing what would have happened if we had the monopoly, but we do not think it would have spread this far. We believe the power behind the explosive diffusion of the QR code was the participation of many companies in the QR market, and the development of better technologies, products, and services through competition with other companies. We were able to advance the QR code by fine-tuning technological development in fierce competition. The technologies that were developed here were utilized in other fields, and keeping the QR code open was successful.

Terminologies

Term 1. QR code: A registered trademark of Denso Wave Inc.

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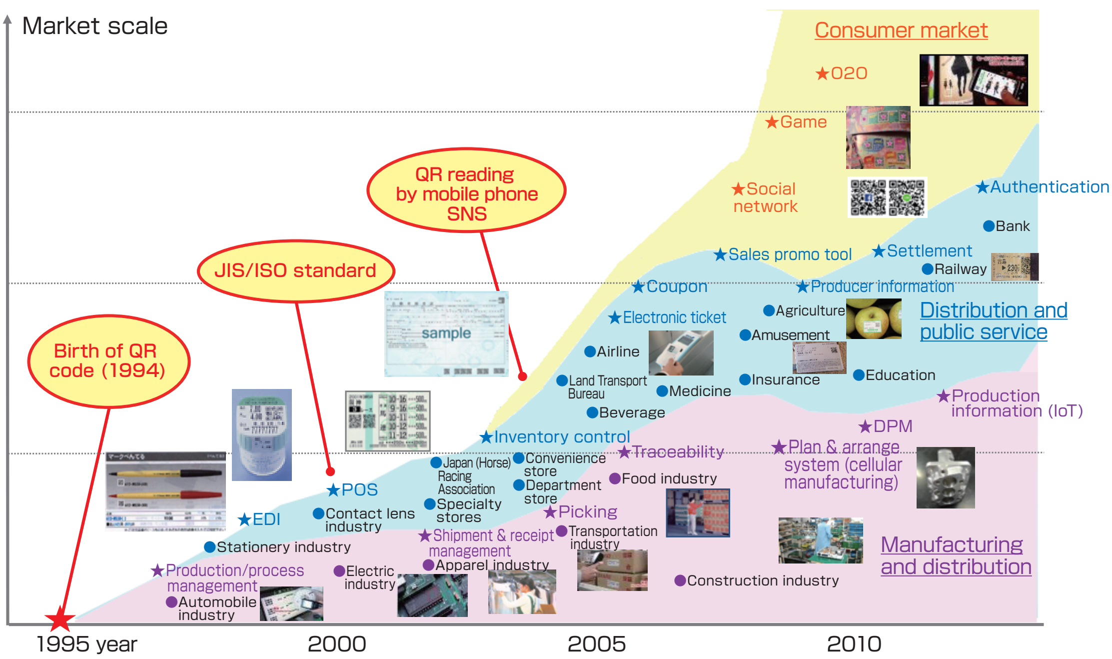

Fig. 7 Diffusion of QR code

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Discussions with Reviewers

1 Overall

Comment (Motoyuki Akamatsu, AIST)

This paper discusses the course of development of the QR code, a two-dimensional barcode, and its diffusion strategy. It explains carefully the technological points of optical codes, including information volume, rotation, and anti-smudge measures. It also presents the goals set based on social situations at the commencement of development, diffusion strategies such as branding, and the fact that a bold policy of disclosing the patent led to wide spread use. It is greatly helpful as a scenario for technological development and diffusion to society.

Comment (Toshihiro Matsui, Institute of Information Security)

The QR code is a widely used pattern code developed by a Japanese company, and is a highly rated system that allows the code to be used freely. To have the course of its development published in *Synthesiology* will help the readers in seeking methods for diffusing original technology.

2 Intellectual property in open-close strategy

Question (Toshihiro Matsui)

You mention that you employed the open-close strategy, but doesn't registering the QR code as a trademark limit its use? I think to disclose the technology while obtaining a patent is a brilliant strategy, but did you consider what kind of patent should be obtained? You say you use the patent to eliminate copies and unauthorized use, but how specifically did you do so? Pertaining to the undisclosed part, at the time of development, did you ever suppose that it will become possible to read the code with a smartphone, without using a special scanning device?

Answer (Masahiro Hara)

Concerning a registered trademark, as the number one strategy for the diffusion of the QR code, we attempted to establish a brand image that the QR code is an excellent code. When the QR code was in the process of diffusion, other 2D codes could have called themselves the QR code. Since the reputation of the QR code could be jeopardized if the performances of those 2D codes were bad, we obtained a registered trademark so other poor quality 2D codes could not call themselves the QR code.

We obtained patents for items that were newly developed for the QR code, to prove that we were not violating any other patent in the disclosed QR code. We prioritized the patents for the reading/scanning devices that are the pillar of our business.

If we found any copy products or unauthorized use, we would issue warnings that they were violating our patent rights, and if they did not stop after receiving the warnings, we would proceed to exercise our patent rights. Up to this moment, we have issued only one warning against a copy product.

When we were developing the QR code, we did not assume that the smartphone would become capable of reading QR codes. Denso considered various B to B usages, but we didn't consider B to C as part of our business due to Denso's corporate culture.

3 Branding

Question (Motoyuki Akamatsu)

You mentioned that branding was one of the strategies. What were your branding measures for "building an image of high-performance, high quality, and security"?

Answer (Masahiro Hara)

By disclosing the QR code and getting many companies to participate, many reading and printing products were created by companies other than Denso Wave. If the product performance of products by companies other than Denso Wave was poor, the excellent characteristic of the QR code could not be presented. Therefore, the know-how of reading and printing was disclosed to ensure minimum performance and quality that would not hinder operation. We created a booklet called *QR Code Dokuhon* (Guide to QR Codes) to get people to understand the excellence of the QR code, and these were distributed to the users as part of our educational campaign.

4 Diffusion of technology through standardization

Question (Toshihiro Matsui)

Your discussion of the diffusion scenario is very interesting. How did you gain usage experience in the early stages, when no one was using the code, and what kind of promotion did you do at the time? Also, at the stage when future potential was unclear, how did you convince your superiors that the development should go on? On the standardization to promote diffusion, what was the background for achieving standardization in six years? What specific actions did you take in borrowing user power in usage development?

Answer (Masahiro Hara)

First, we obtained opportunities to do presentations for the QR code at various industrial meetings, where we conducted demonstrations for high-speed scanning and accurate reading even when the code was smudged or damaged. We later visited the companies that showed interest, offered detailed explanation of the QR code, and these efforts led to adoption.

At the beginning, since we didn't know whether we would be successful, we started with two people and started from code development that did not involve any development cost. We convinced our superiors that we would move to reading device development only after the code was completed and if people showed interest when we did demonstrations in front of potential users. Therefore, product realization of reading devices was started two years after the completion of the QR code.

For standardization, we were able to do so quickly, because we aggressively built experience in the automobile, electric/electronic, and distribution industries that were engaging in global business, and the industries themselves requested ISO standardization.

For usage development, we listened to the users who discussed the issues in their daily operation and how they wanted to be, and we proposed methods to realize their demands using the QR code.

5 Characteristic technology of QR code

Question (Toshihiro Matsui)

In Chapter 4, you explain the ease of use, volume, reading performance, and reliability of the QR technology. I think one of the definitive characteristics of the QR code is the finder pattern. The finder pattern is unique as a printed matter, can be detected even if rotated, and is readable by one-dimensional linear scanning. However, if you were looking for rotational invariance, why didn't you use concentric circles?

Answer (Masahiro Hara)

The reason why we did not make the finder pattern in concentric circles is because when the code is printed with a low-resolution printer, the circles must be made bigger. Compared to squares, circles require more dots in printing. Considering that codes may have to be printed in small printing areas, we decided to use squares.

6 Difference from competitor technology

Question (Toshihiro Matsui)

How is the situation of the diffusion of the QR code overseas? In the field of pharmaceuticals, Datamatrix and Databar Limited have been standardized, but how are they different from the QR code?

Answer (Masahiro Hara)

The QR code is used widely around the world. Databar Limited is a type of barcode, and it cannot hold a lot of information. Therefore, it is not used much in areas other than pharmaceuticals. Datamatrix is used in American industries for data up to 40 digits, but the reading performance drops if it is packed with information. Therefore, the QR code is widely used for usage that involves storing lots of information.

7 Evolution of QR code

Question (Motoyuki Akamatsu)

You mentioned that you intend to “evolve the QR code according to social demands.” You give specific examples of evolution such as iQR, SQRC, and illustration design. What were the points in making it capable of handling a great deal of information?

Answer (Masahiro Hara)

To accurately read much information quickly, we worked on data arrangement and readable code composition (arrangement of functional cells) considering code recognition technology. We also worked on reducing the size of code as much as possible by efficient compression. For example, Level 1 and Level 2 JIS kanji characters are compressed to 13 bits, and “https://www.” and other keywords frequently used in industry are set as 1-bit reserved words.