Applying QR Code in Augmented Reality Applications

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Abstract

In this paper we present an augmented reality (AR) application based on the QR Code. The system can extract the information embedded in a QR Code and show the information in an extended 3D form with the QR Code being the traditional AR marker. Traditional AR systems often use a particularly designed pattern (the marker) to recover the 3D scene structure and identify the object to be displayed on the scene. In these systems, the marker is used only for tracking and identification. They do not convey any other information. Consequently, the applications of these systems are limited and often a registration procedure is required for a new marker.

QR Code has the advantage of large information capacity and is similar to an AR marker in appearance. Thus, more interesting and useful applications can be developed by combining the QR Code with the traditional AR system. In this paper, we combine these two techniques to develop a product demo system. A QR Code is pasted on the package of a product and then a 3D virtual object is displayed on the QR Code. This system allows the customer to visualize the product via a more direct and interactive way. Our system demonstrates the success of using QR Code as the AR marker to a particular application and we believe it can bring more convenient to our life in the future.

CR Categories: H.5.1 [Information Interfaces and Presentation]: Multimedia Information Systems—Artificial, augmented, and virtual realities; I.3.7 [Computer Graphics]: Three-Dimensional Graphics and Realism—Virtual reality;

Keywords: Augmented reality, QR Code, 2D barcode, ARToolKit

1 Introduction

Recently, the 2D barcodes have been extensively developed to encode large volume of information in many applications. Among the 2D barcode systems, the QR Code is widely used because of its high reading speed, high accuracy, and superior functionalities. As a result, QR Codes are widely used not only in its original country, Japan, but also in many other countries now.

QR Code, initial of Quick Response Code, is a 2D matrix barcodes developed by Denso Wave Corporation in 1994. As Denso Wave pointed out in its website [Denso Wave Corporation 2000], QR Code is capable of handling many types of data, such as numeric and alphabetic characters, Kanji, Kana, Hiragana, and so on. It can encode up to 7,089 numeric characters or 4,296 alphanumeric characters in one pattern. In addition, unlike many traditional 2D barcodes that need to be decoded by a specific scanner, QR Code can be decoded by a small program in a cell phone or a personal computer with built-in camera. So far, the QR Codes are mainly used in the areas such as digital contents download [Parikh and Lazowska 2006] and products information storing [Seino et al. 2004]. Since digital contents can be downloaded and read through a QR Code anywhere [Chen 2007], some applications such as Handheld English Language Learning Organization (*HELLO*) [Liu et al. 2007] are constructed based on the QR Code. This system employs QR Code and augmented reality technique to support a context-aware learning which aims to improve the student's English level. However, in this system the QR Code is used only as an information communication media, which is independent on the AR they used. Moreover, the AR they employed is also different from the traditional marker-based AR system.

Augmented reality is a technology combining real environment with virtual objects. Usually, in a AR system the users can interact with the virtual objects in real time [Azuma 1997]. Several successful AR systems, including *ARToolKit* [Kato and Billinghurst 1999], *ARToolKitPlus*[Christian Christian Doppler Laboratory 2003] and *ARTag* [Fiala 2004], have been developed and are widely used in the augmented and mixed reality applications. Some AR applications have also been used in industry and commercial activity such as *metaio Unifeye* [metaio 2003] and *CyberCode* [Rekimoto and Ayatsuka 2000]. However, in these marker-based or tag-based applications, the marker is used only for the recovery of the 3D scene structure and the identification of the virtual object to be displayed on the screen. Often, they also required a registration process each time a new pattern or a new object is included in the system. Obviously, this will limit the possible applications of these systems. Moreover, the increased number of markers to be matched will also degrade the identification speed of these systems.

QR Code is quite similar to an AR marker in appearance (Fig. 1), but can encode more information then traditional markers. Therefore, if we can combine the advantages of QR Code and AR technique by letting the QR Code being the traditional marker, we can simplify or omit the registration process of traditional AR systems. In addition, by exploiting the large volume of information a QR Code can encode, we can develop more interesting and useful applications. In this paper, we present a method to determine the relationship of the three position detection patterns of a QR Code (Fig. 2). Based on this information, we can transfer the QR Code to an AR marker, and meanwhile preserve the flexibility of QR Code. By letting the QR Code as a marker, we develop a product demo system to visualize the product in a 3D form. However, although a QR Code can embed larger volume of information than traditional barcode, it may still insufficient to embed a complex 3D model that to be placed on the marker. Fortunately, with the advance of Internet and wireless communication, the communication bandwidth has been increased to a level allowing the users to download a complex model to a mobile device in a very short time. Hence, if a customer wants to acquire detail information about the products before buying them, he can use our system to capture the QR Code via a camera and then a complete 3D model of the product will be shown on the screen via the Internet URL (Uniform Resource Locators) encoded in the QR Code. In the following, we first give an overview of QR Code and then describe our system in more details.

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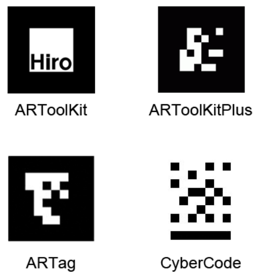

Figure 1: *Similar Fiducial Markers [Kato and Billinghurst 1999][Christian Christian Doppler Laboratory 2003][Fiala 2004][Rekimoto and Ayatsuka 2000].*

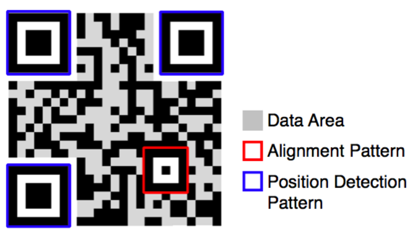

Figure 2: *QR Code Structure.*

2 QR Code

2.1 Overview

QR Codes are specially designed 2D matrix barcodes as illustrated in Fig. 2. In a QR Code, there are three large square patterns (inside each is a small black square surrounding with white bars) in the three corners of the code. These three square patterns are used for position detection. In version 2 (and above) of QR Code, an additional square is used to align the QR Code as shown in Fig. 2. The other area of QR Code consists of a number of small blocks which are used to encode the embedded information. There are several different error correction levels for a QR Code as listed in Table 1. Typically, higher correction level indicates that it allows more blocks in the code to be destroyed, and often this will result in a longer code with larger QR Code size.

Table 2 shows a comparison of QR Code with other tagging technologies. Printable indicates whether the tag can be printed by a printer, and battery means whether the tag requires power. Rewritable denotes whether the content in the tag can be rewritten, and line-of-sight indicates whether the tag should be "viewed" by a detection device. The advantages of visual based tags such as QR Code and visual tags are they can be easily generated by ordinary printers and do not require any batteries. As for QR Code and visual tags, QR Code can embed larger volume of information than visual tags. Moreover, the three position detection patterns of a QR Code can be used for our AR tracking while visual tags do not. In our application of product demo system, the 3D model of a product is stored in a remote server via a URL embedded in the QR Code, thus the rewritable property is not so significant since we can modify or change the model directly from the remote server.

Table 1: *Error correction level of a QR Code [Denso Wave Corporation 2000].*

Level L	Approx. 7% of codewords can be restored
Level M	Approx. 15% of codewords can be restored
Level H	Approx. 25% of codewords can be restored
Level Q	Approx. 30% of codewords can be restored

Table 2: *Features of tagging systems [Rekimoto and Ayatsuka 2000].*

	QR Codes	Visual Tags	RF Tags	IR Tags
Printable	yes	yes	no	no
Line-of-sight	required	required	not required	required
Battery	no	no	no	required
Rewritable	no	no	yes/no	yes/no

Table 3: *Comparison of QR Code with fiducial markers.*

	QR Codes	Fiducial Markers
Need to pre-register	no	yes
Model storing	Internet	local
Limited number of markers	larger	smaller
Universality	universal barcode	stand-alone

2.2 Why QR Code

Why do we use a QR Code as an AR marker? Table 3 shows a comparison of QR Code as an AR marker with other fiducial AR markers.

We think the distinctions between our system and traditional AR systems are that fiducial marker based systems usually need a registration process each time a new pattern or a new object is included in the system. On the other hand, our system does not need to register any marker when a new QR Code appears on the camera screen. The information in any QR Code can be extracted by our system without difficulty.

Typically, traditional marker systems often store the models in a local server. This manner may sometimes restrict the applications of these AR systems.*Webtag* [Fiala 2007], an AR system developed later, tries to let the marker serving a media which provides a link to the content. *Webtag* can decode an ID from tier-2 (a concept similar to nested AR marker [Tateno et al. 2007]) of the marker, then sent the ID to a website to index a full URL where content stored. Overall, in *Webtag*, the marker can be used both for AR tracking and virtual content addressing. This tell us that it is a trend to put the markers and content out of local server so as to cost-down and save the resource of local system. Our system use a URL embedded in the QR Code to access the models in a remote server, thus our system has also the advantage of avoiding storing the models in the local server. Moreover, the models in the remote server can also be easily modified via Internet, thus our system is more flexible than traditional marker based systems.

As Mark Fiala points out [Fiala 2007], all traditional AR systems suffer from the same problem of limited number of markers. To solve this problem, he extended his *ARTag* to *Webtag* so that it can address $4x10^{12}$ unique possibilities. However, since a QR Code can encode a maximum of 7,089 numeric characters, our system can address maximally 10^{7089} possibilities. Because of the large volume of information a QR Code can embed, our system does not have the problem of traditional AR systems with limited number of markers.

Another problem of the traditional AR systems is that their makers are not public or universal markers. In some conditions, these kinds of markers will limit the development and promotion of the AR system. However, our system do not have this problem since QR Code is a widely used 2D matrix barcode in many other areas.

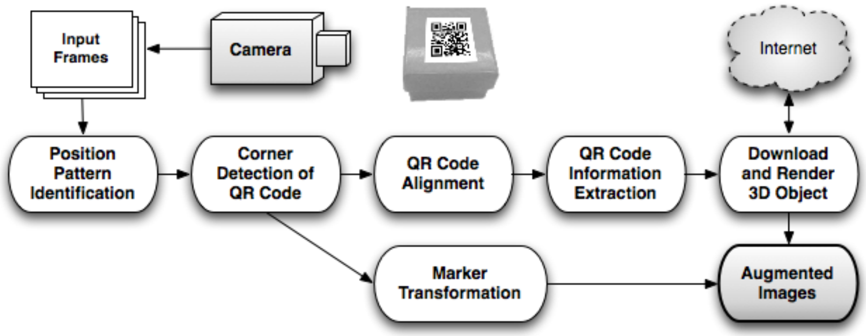

Figure 3: *System Architecture*

3 Tracking and Aligning QR Code

Our system is designed to track the QR Code so that it can replace the traditional AR marker. The system does not require modifying any structure of a QR Code, thus our system is different from traditional AR system where they need to pre-register the AR marker to determine which 3D model the marker corresponds to. In the following, we will first give an overview of our system and then present the detailed mechanism of each module in our system.

3.1 System Architecture and Advantages

The architecture of our system is shown in Fig. 3. We use *ARToolKit* as a developing platform. The position detection pattern in a QR Code is registered as a tracking marker in *ARToolKit*. Thus, after identifying patterns by *ARToolKit*, typically we can detect the three patterns at the three corners of a QR Code. We then find the final corner of the QR Code by exploiting the spacial relationship of the three detected corner patterns. By the information of the four corners, the QR Code can then be transfered to a traditional AR marker which can be used to place and orient the 3D model. Meanwhile, the positions of the four corners can also be utilized to align the QR Code, so that the information embedded in the QR Code can be extracted more accurately. From the extracted information, we then download a 3D model from a remote server via Internet, and finally, the 3D model is rendered on the QR Code.

From the simple description of our system, it has the following advantages:

- Our system does not require a pre-registeration procedure for a new QR Code. When a QR Code is identified by the system, the system will download a 3D model via Internet URL from the information embedded in the QR Code. Subsequently, the 3D model is rendered on the QR Code in real-time.
- The AR marker (QR Code) in our system has multiple functions now. It can serve as the pattern to recover the 3D scene structure and meanwhile has the capability of encoding a large volume of information in it. Moreover, our system also preserves the advantage of QR Code. For example, it can restore a maximum of 30% codewords through the setting of error correction level.
- Some QR Code programs do not support the recognition of perspective distorted QR Code. Our system can overcome this problem by correcting the QR Code via a perspective transformation.
- Our system provides a novel way for promoting a product. It can enhance buyers' confidence before purchasing the packaged products since they can "see" the virtual product in a intuitive way.

3.2 Tracking QR Code

We use *ARToolKit* to track the three position detection patterns of a QR Code. If *ARToolKit* detects a pattern with confidence value grater than 50%, then this pattern is recognized as a candidate of a position detection pattern. The QR Code tracking will be activated if three candidates are detected in the current frame. Currently, we use a simple counting mechanism to ensure the finding of the three position detection patterns. However, a sophisticated approach can be applied to find the patterns more accurate. In fact, by *ARToolKit* we can find the 3D positions of the patterns, thus we can filter out those incorrect patterns by exploiting the spacial relationship of the three patterns since the correct patterns are arranged at a right triangle as illustrated in Fig. 4.

After locating the three position detection patterns, we then determine the position of the fourth corner of a QR Code. Actually, *ARToolKit* can tell us the center positions of the three position detection patterns as well as the four corners of each pattern. Thus, if we can determine the outer vertices of the two diagonal position detection patterns (i.e., the vertices B_1, B_2 and D_1, D_4 in Fig. 5(b)), then by simple computation we can obtain the fourth corner of a QR Code (Fig. 5(d)). However, the problem is that we do not know which points detected by *ARToolKit* correspond to the outer vertices of the two diagonal patterns. Note that the detected points are in an image plane which suffers a perspective distortion, thus the usual Euclidean geometry quantities such as distance and angle are not preserved under this situation. Our procedures for determining the fourth corner of a QR Code are listed in the following and illustrated in Fig. 5.

1. Identify the two diagonal position detection patterns (patterns B and D in Fig. 5) of a QR Code. Typically, the non-diagonal pattern (pattern A) will face the longest side of the triangle formed by the three patterns. Thus, theoretically by computing the distances between the three patterns, we can find pattern A and therefore patterns B and D. However, due to the perspective distortion, the above relation sometimes may not be satisfied. Fortunately, *ARToolKit* also provides the 3D positions of the centers of the three patterns, thus by computing the 3D distances of these patterns we can accurately determine the two diagonal patterns of a QR Code.
2. Determine the central coordinates of a QR Code by calculating the midpoint P_0 of the two diagonal patterns as shown in

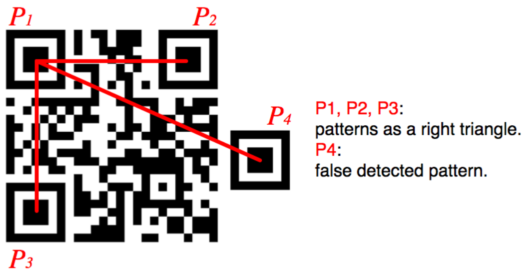

Figure 4: *Solving the problem of multi-detection of position detection patterns.*

Fig. 5(a).

3. Find the vertex A_1 by comparing the distances of each corner of pattern A to the central point P_0 as illustrated in Fig. 5(b). The point with the longest distance is the vertex A_1. Note that distance is not preserved under perspective transformation, but in our experience the relations between these distances are seldom broken in our experiments.

4. Determine the vertices B_2 and D_4 by comparing the distances of each corner of patterns B and D to the point A_1 as revealed in Fig. 5(c). The point corresponding to the longest distance of each pattern is the vertex we desired.

5. Locate the vertices B_1 and D_1 by comparing the distances of each corner of patterns B and D to the central point P_0. The points farthest to P_0 are B_1 and D_1.

6. Determine the fourth corner of the QR Code by computing the intersection of lines B_1B_2 and D_1D_4 as illustrated in Fig. 5(d).

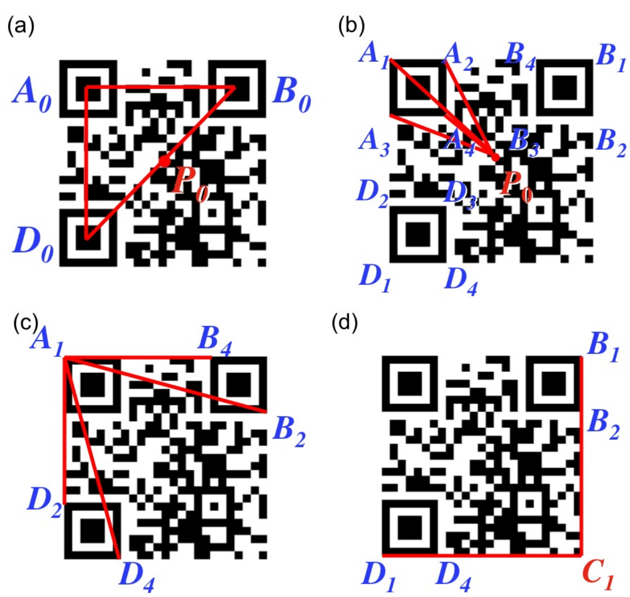

Figure 5: *QR Code Recognition Steps*

After determining the fourth corner of a QR Code, *ARToolKit* can then locate the plane of the QR Code in the 3D world and subsequently a 3D model can be placed on the QR Code, allowing the user to visualize the 3D model.

3.3 QR Code Alignment

After locating the QR Code in a 3D world, we then aim to extract the information embedded in the QR Code. There exists some open software that can be used to decode the information in a QR Code (e.g. [Takao 2007]). However, some programs require the QR Code to be placed exactly in front of the camera so that the information can be correctly extracted. However, in our system the QR Code is used as an AR marker, thus it is infeasible to demand the user to put the QR Code in a specific position and orientation. Hence, to meet the requirements of these programs and improve the flexibility and accuracy of QR Code decoding, we must align the QR Code to facilitate the information extraction of a QR Code.

Since the QR Code is projected from one plane on the camera image plane, we can restore its orientation by the following perspective transformation:

$$\begin{bmatrix} u_i \\ v_i \\ w_i \end{bmatrix} = \begin{bmatrix} a & b & c \\ d & e & f \\ g & h & 1 \end{bmatrix} \begin{bmatrix} x_i \\ y_i \\ 1 \end{bmatrix} \tag{1}$$

where (x_i, y_i) are the original coordinates of the QR Code and (u_i, v_i, w_i) are the aligned homogeneous coordinates of the QR Code. The 8 unknown entries of the transformation matrix can be estimated by four corresponding points, which is quite easy since the coordinates of the four corners of the QR Code have been determined. After estimating the perspective transformation matrix, we can then transform the QR Code to a proper orientation as shown in Fig. 6.

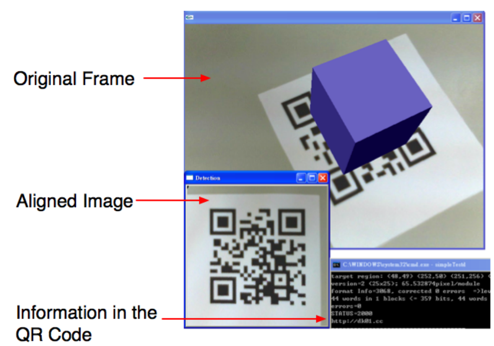

Figure 6: *QR Code Alignment.*

4 Product Demo System

To demonstrate the feasibility of using QR Code as an AR marker, we developed a product demo system which allows a customer to visualize the packaged product in a 3D form. Currently, the information embedded in the QR Code is just a simple URL indicating the 3D model to be downloaded and displayed on the scene. However, because of the large volume of data a QR Code can encode, we can put more information about the product such as a detailed specification or a simple user guide in the code. This can serve as a backup solution when the Internet is unavailable so that the 3D model can not be downloaded.

At present, the QR Codes we used are generated by a freeware program called QR Code Editor [Psytec Inc. 1999] and we paste the code onto the package to simulate the practical situation for using this system. Figure 7 shows a picture of imposing the QR Code onto the package of a camera (our product). Figure 8 displays the generated 3D visual camera on the QR Code from different viewpoints.

The customer can manipulate the virtual camera by operating the QR Code on the package. Currently, the system is only a prototype thus its functionality is limited. Only a 3D model is shown on the QR Code. However, the system has the flexibility to incorporate more functions into the system, thus enhancing its usability and practicability in the future.

Figure 7: *Pasting a QR Code on the package of a product (camera).*

Figure 8: *A 3D virtual camera from different viewpoints.*

5 Conclusion

In this paper, we proposed a mechanism that employs the QR Code as the traditional AR marker and devised a product demo system based on this QR Code marker. Our system has the advantage that any QR Code can be used as the tracking marker without any pre-registration process. Meanwhile, the information embedded in the QR Code can also be extracted even the QR Code is not facing the camera exactly. The embedded information can be used to represent a URL so that a 3D model can be downloaded directly from the Internet. This implies that we can change the content without modifying the QR Code. Thus, the system is very flexible so that it can be easily extended to many other possible applications without difficulty. At present, our product demo system is just a simple static visualization of the product. In fact, some animations and user interaction can also be included in the system, making the system more attractive and functional. For instance, we can guide the customer how to assemble the product step by step via an animated 3D video. We think that the success of this system will trigger many other useful and interesting applications in the future.

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