Diverse Augmented Reality Exhibitions for Differential Users Based upon Private Quick Response Code

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***Abstract*—The marker-based augmented reality (AR) system can produce 3D virtual object to satisfy the user interaction in the real-world. The marker is a tag/pattern and used to help the AR system to locate the corresponding virtual object on the scene. The marker, however, needs to be designed firstly and the recognition capability is limited. The exhibited virtual object and the marker, unfortunately, are linked in the AR system. Hence, such conventional AR system treats all users as the same role. In this article, we proposed a diversity AR system that can provide the differential virtual objects exhibitions for specific users, such as the joint member and different degree person. The new schemes exploited the error correction capability of QR barcode to conceal the individual secret stream of users into a QR marker. Consequently, the general user can only observe the normal 3D virtual object on the marked QR tag. The assigned members can further reveal the various virtual objects from the same QR tag. The proposed diverse AR system can distinguish different users from same QR marker and thereby exhibit the corresponding virtual objects. The new system is practical and can be widely applied in specific customer AR applications.**

I. INTRODUCTION

Augmented reality (AR) technology [1-4] can provide user experience and interaction by exhibiting illusion from the human visual perception in the real environment. The major process of AR system is to find the camera tracking and pose information according to a marker [5-7] or natural features in the scene. With the estimated information, AR superimposes the corresponding virtual object on the marker or the real scene with appropriate location. By combining the virtual object with real environment, AR is widely applied in commercial, education, entertainment, and industrial design.

To estimate the camera tracking and pose effectively, the marker-based AR system is commonly used [8-10]. The marker is a pattern or a tag that consisted of black and white patterns for sake of being detected and recognized easily. In the marker-based AR system, the marker should be pre-defined and registered in the system firstly. The link of the marker and the corresponding virtual object afterward is associated together.

Fig. 1 depicted the process of AR system. With the help of the marker, a camera can efficiently recognize the tag while capturing the real scene image. AR system afterward can estimate the camera tracking and pose. The pre-defined virtual object can be appropriately located on the marker with the estimated rotation degree and translation.

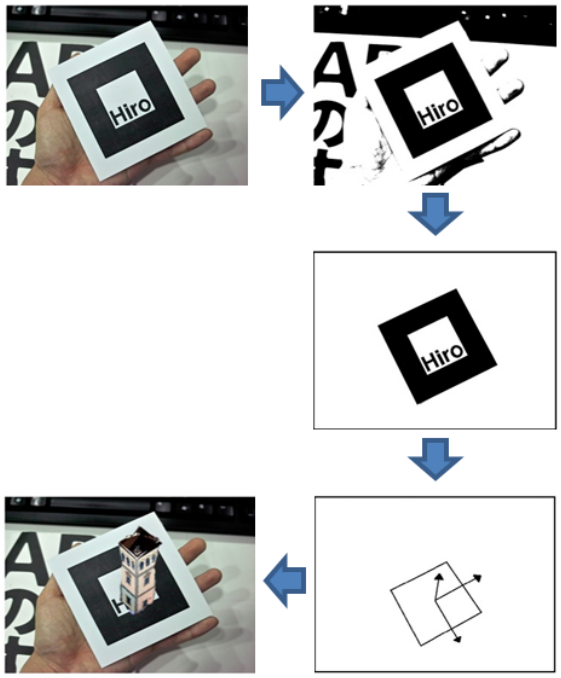


Fig. 1 An instance of the marker-based AR system.

The marker registration process of marker-based AR system, however, is unsuitable for public domain. That is, the marker should be registered to the system before using. And the link between the marker and the corresponding virtual

object is pre-defined and uniform in AR system. This reduces the flexibility of dynamic changing the virtual object in AR system.

To provide dynamic link of a marker and the corresponding virtual object without registration in advance, the quick response (QR) barcode is utilized to replace the traditional marker in AR system [8-10]. QR barcode [11, 12] is a type of two-dimensional symbol that developed by Denso-Wave company. Different from one-dimensional barcode, QR barcode can carry greater data capacity and capable of resisting damage.

Similar to the marker in AR system, QR tag is consisted of white and black modules (square dots). The white module and black module represent binary value zero and one, respectively. With the barcode reader, the data content of QR tag can be encoded and decode effectively.

Based on the practicability of QR tag, many researches have focused on adopting QR tag instead of the marker in AR system [8-10]. In the schemes, a link is encoded into a QR tag. Here, the link can be a uniform resource locator (URL) and can be assigned to any virtual object dynamically. The data content, i.e. the URL, of the QR tag can be revealed by barcode scanner. With the URL, AR system can download and render the virtual object on the QR tag. Consequently, AR system can accept any QR tag and produce the linked virtual object on the QR tag without any registration procedure.

Unfortunately, the common AR system [1-10] treats all users as the same role. AR system produces the same virtual object to all users who possesses the same marker. In the real word, users normally have different capacities, positions or degrees. Hence, users should be classified and assigned the suitable virtual object according to their roles. To the best of our knowledge, the recent AR schemes are incapable of providing the differential AR exhibitions between the general user and the specific users with a same marker.

Inspired by this observation, we aim to provide a diverse augmented reality (DAR) system that can render various virtual objects to differential users with a same marker. The proposed DAR mechanism utilizes the concept of steganography technique [13, 14] to conceal the specific secret streams of users into a QR marker. Moreover, DAR can preserve the original date content of the marked QR tag for ensuring the decodability of QR tag. The proposed DAR can extend the AR application widely. For example, a store can show the normal virtual object to general customers, and can further show the associated virtual objects to the members, such as the favorite or recommend accessories (purse, ring, and scarf). For the education application, the learning system can produce different learning levels of virtual objects according to the users' degrees. With the diverse AR exhibitions, the proposed DAR is practical and effective for real-world AR applications.

II. The Generation of Marked QR Tag

In the proposed diverse augmented reality (DAR) system, let there are one role of general user, U, and m roles of special users (members), U_1, U_2, …, U_m. And let the normal virtual object for all users are O, and the m specific virtual objects for U_1, U_2, …, and U_m be O_1, O_2, …, and O_m, respectively.

Let QR be a given QR tag that derived by QR barcode generator [15, 16]. The data content of QR can be a uniform resource locator (URL) or a link of the normal virtual object O. That is, all users U, U_1, …, U_m, can observe the normal virtual object O from QR. According to the QR barcode standard, let n be the number of QR data and error correction modules of QR. The blue area of Fig. 2 shows the data and error correction codewords.

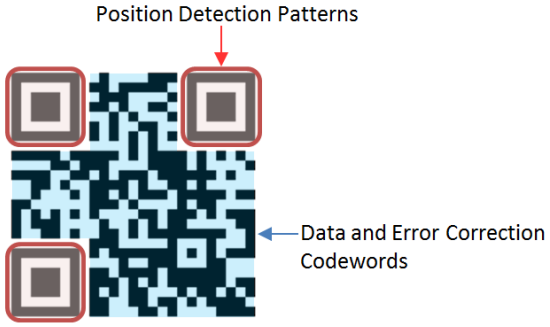


Fig. 2 The modules of data and error correction codewords of QR tag.

To distinguish the general user, U, and the specific members, U_1, U_2, …, U_m, let ID_i and s_i be the member identification number and the secret of U_i, $1 \le i \le m$. Here, s_i is a binary stream, $s_i \in \{0,1\}$, and the length of s_i is $\lceil \log_2 m \rceil$. The stream c_i corresponding to ID_i can be computed,

$$c_i = H_K(ID_i) \bmod n. \tag{1}$$

Here, K is the secret key of the dealer in AR system, and $H_K(\cdot)$ is a one-way hash function with the key K. The length of c_i is $\lceil \log_2 m \rceil$.

To derive QR with specific secret stream of users, the concept of steganography technique [14] is adopted to conceal the secrets s_i into QR. Assume that q_{i1}, q_{i2}, …, $q_{i\lceil \log_2 m \rceil}$ are the $\lceil \log_2 m \rceil$ modules of c_i in QR, and s_{i1}, s_{i2}, …, $s_{i\lceil \log_2 m \rceil}$ are the $\lceil \log_2 m \rceil$ bits of s_i. The secrets s_i thereby can be concealed into c_i, for i=1, 2, …, m, by modifying the modules q_{i1}, q_{i2}, …, $q_{i\lceil \log_2 m \rceil}$ of QR,

$$q'_{ij} = q_{ij} \oplus s_{ij}., j=1, 2, \ldots, s_{i\lceil \log_2 m \rceil}. \tag{2}$$

where, q'_{ij} is the modified result of q_{ij}. After the concealment, the marked QR tag QR' subsequently can be obtained.

Considering the decodability of QR, the concealment of s_i should be restricted in advance. Hence, the value of m should be restricted with the equation,

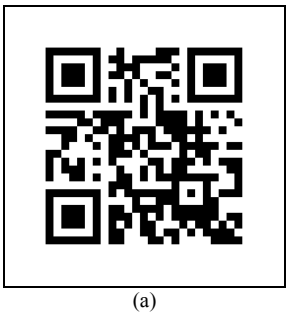
$$m \times \lceil \log_2 m \rceil \le \lfloor EC/2 \rfloor \times 8. \tag{3}$$

The parameter *EC* is the number of error correction codewords of *QR*.

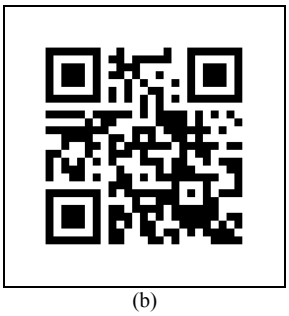
Table I lists the error correction capability of QR system. That is, QR barcode can decode and retrieve the data content correctly while the damage of QR modules is lower than the error correction level. Based on the advantage of error correction capability of QR tag, we utilized the property to preserve the data content of *QR* with limiting the modified number of modules.

TABLE I
THE ERROR CORRECTION CAPABILITY OF THE QR BARCODE

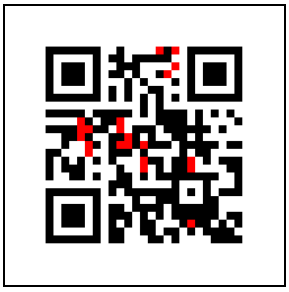
Error Correction Level	Error Correction Capability, % of codewords
L (Low)	7 %
M (Medium)	15 %
Q (Quartile)	25 %
H (High)	30 %



(a)



(b)



(c)

Fig. 3 The results of the concealment QR tag.

Fig. 3 shows the results of the marked QR tag for eight roles of special users (members), m = 8. Fig. 3(a) is the original QR tag with the data content "http://www.yzu.edu.tw/". Fig. 3(b) displays the marked QR tag with concealing 24 bits into Fig. 3(a). That is, 8×3 bits = 24 bits. The red modules in Fig. 3(c) depicted the difference between Fig. 3(a) and Fig. 3(b).

III. THE EXHIBITION OF DIVERSE AR

The general user, U, can observe the normal virtual object, O, from the marked QR tag QR' by scanning the QR tag with AR system. To further exhibit the m specific virtual objects O_1, O_2, …, and O_m, for the corresponding members U_1, U_2, …, and U_m, the secret s_i can be obtained by retrieving the $\lceil \log_2 m \rceil$ modules of c_i in QR', $1 \le i \le m$. Here, the stream c_i can be generated by the member identification number ID_i of U_i,

$$c_i = H_K(ID_i) \bmod n. \tag{4}$$

Here, K is the secret key of the dealer in AR system, and $H_K(\bullet)$ is a one-way hash function with the key K. The length of c_i is $\lceil \log_2 m \rceil$.

Consequently, with the extracted secret stream s_i, the assigned virtual object O_i can be rendered to the individual member U_i, $1 \le i \le m$. In the AR system, to estimate the camera pose form the marked QR, the corner-based approach [9, 10] with ARToolKit [17] is utilized in our DAR system. Firstly, the position detection patterns (the red regions of Fig. 2) of QR tag is registered as AR marker in ARToolKit.

While camera captures the scene image, ARToolKit can detect and identify the three position detection patterns. The parameters X_0 and X_1, X_2, X_3, X_4 in Fig. 4(a) indicate the center and the four corners of a position detection pattern by corner-based approach [9, 10]. That is, with the three detected position detection patterns of QR, ARToolKit can locate the corresponding center A_0, B_0, and C_0 (as shown in Fig. 4(b)), and the four corners, A_1 to A_4, B_1 to B_4, and C_1 to C_4, as depicted in Fig. 4(c). The fourth corner, D, afterward can be derived. Fig. 4(e) shows the estimated fourth corner from Fig. 4(c) and Fig. 4(d).

With the four detected corners, the world coordinate system can define X and Y axes of QR' by rectifying QR'. The feature of camera pose thereby can be estimated by exploiting homography between the captured image and the established feature map of QR'. The rotation degree R and the translation T between camera and QR' can be derived [9, 10].

Fig. 5 demonstrates the overview of the proposed DAR system. ARToolKit can capture the marked QR' and then estimate the camera pose, such as the rotation matrix R and translation T (R&T). The date content of QR' can be decoded by barcode reader. With the data content (URL), the normal 3D virtual object can be linked and downloaded. According to R&T, the virtual object can be exhibited on the scene QR' image with appropriate location. That is, the general users can observe the normal 3D virtual object. For the specific member with their own ID_i, DAR can further extract the corresponding secret s_i by the system key K automatically. The assigned

virtual object O_i according to s_i, thereby can be rendered to the specific members U_i. The diverse AR exhibition is practical to produce the various virtual objects for differential users.

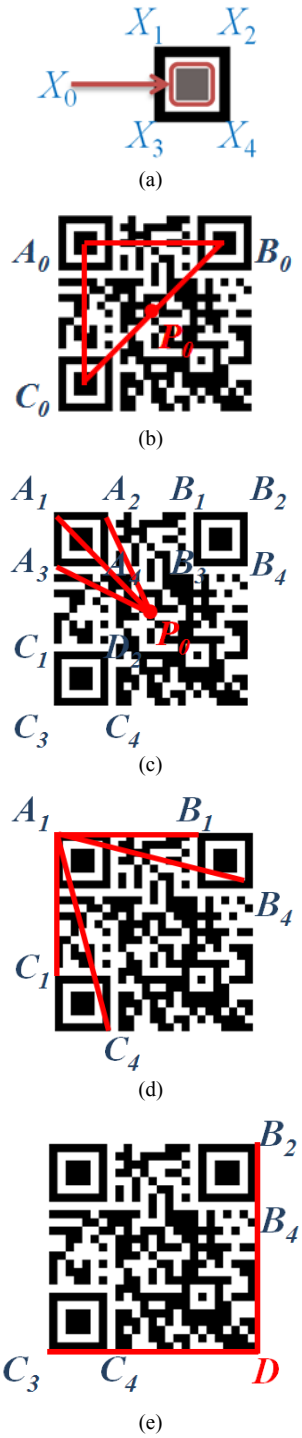


Fig. 4 The corners finding process of a QR tag.

IV. Conclusions

The designed diverse augmented reality (DAR) mechanism is practical and can be widely applied to distinguish different degree/role of users in AR applications. The new scheme produces various virtual object exhibitions to specific users according to their position with the same marked QR tag. Besides, DAR can satisfy the requirement of the public domain AR without any registration process in advance. DAR preserves the original data content (link or URL) of the derived marked QR tag. The data content can be decoded correctly by barcode reader without distorting the decoding ability. With the decoded data content, the virtual object can be linked and downloaded dynamically. The differential exhibitions of DAR extend the feasibility for value-added AR applications.

Acknowledgment

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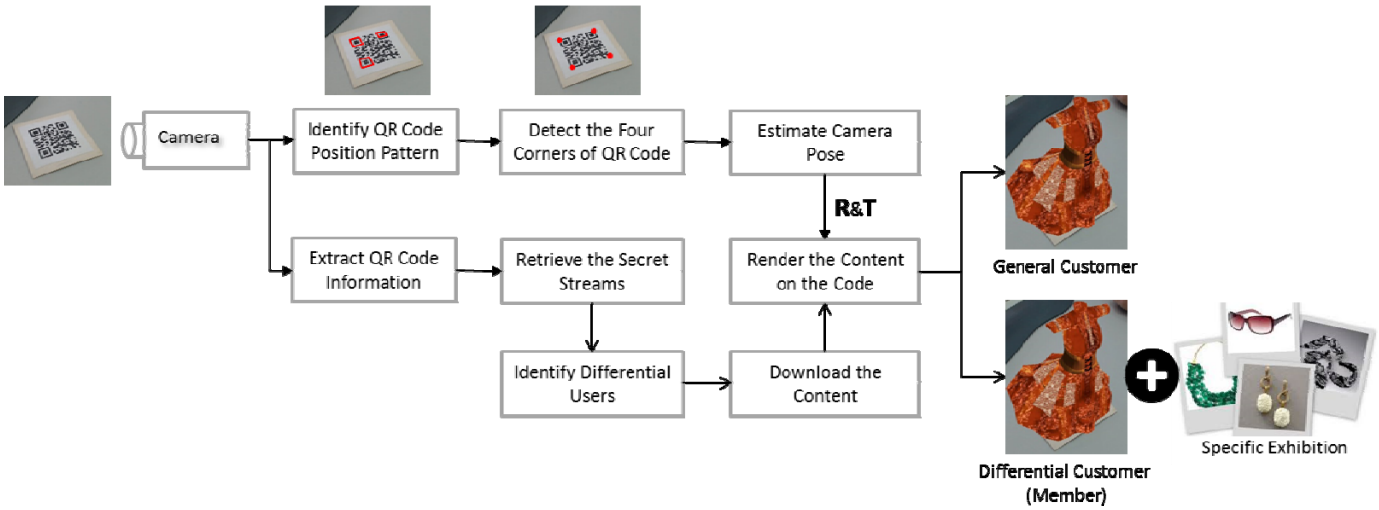

Fig. 5 The overview of the proposed system.