Augmented Reality Serious Game Framework for Rehabilitation with Personal Health Records

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***Abstract*—Users interact with most electronic entertainment games via some specific electronic sensors, which are not part of the existing equipment in most household. As well, some electronic entertainment games claim to have medical rehabilitative effects. This research designs a series of web-based serious games (SGs) for rehabilitation utilization with a proposed framework that lets family users easily connect through the Internet without the need for special sensors. This system includes diverse SGs for different rehabilitation levels. Users can operate these SGs via mouse or hand movements. Therefore, it is not necessary for patients to buy or rent any extra rehabilitation equipment; all that is required is a personal computer at home. Some of these SGs are adapted to augmented reality technology. This system also connects directly with personal health records in order to log every rehabilitation activity. In addition, social networks, such as Facebook, can be used for connecting rehabilitation patients at home with each other. By simplifying access, this rehabilitation SG system increases the frequency of rehabilitative activity of patients at home.**

Keywords- Augment reality, cybercare, digital camera, health information management, medical information system, patient rehabilitation, personal health records.

I. INTRODUCTION

The definition of the telemedicine is illustrated by the American Telemedicine Association (ATA) such as the use of medical information exchanged from one site to another via electronic communication for the health and education of the patient or health care provider and for the purpose of improving patient cares [1]. Generally, the following subsections describe the latest information technologies and concepts to let the proposed framework achieve the tele-rehabilitation effects in the Internet.

A. Augmented Reality

The Augmented Reality (AR) is the extension of the Virtual Reality (VR) that creates a virtual environment and let users simulate some actions. The AR utilizes traditional pattern recognition technology to let some real information be marked in the necessary objects and to achieve the augmented effects. That is, the AR technology is a combined presentation of virtual and entity. The major purpose of the AR is to provide an environment to let users interact between virtual and real worlds and to meet our expected effects. The AR technology is proposed in 1990. In order to expand the AR adopting scopes, Azuma defined the AR as systems with the following three characteristics, such as combining real and virtual objects, interacting in real time, and registering in three-dimensional (3D) observation [2].

The AR utilization scope at least includes educational, military, and medical fields. In the teaching field, the combination of e-books lets the teaching contents more interesting than ever and attracts more learners to enjoy the learning. In the medical field, the AR technology is mostly utilized in surgery operation for 3D positioning. However, we can also discover some cases for rehabilitation serious games (SGs) with AR technology. Such a SG can let user active his or her body and achieve the specific rehabilitation effects. Because our proposed idea is to utilize the AR technology as a rehabilitation SG basis and to record related rehabilitation data online, it is necessary to further understand the personal health records in order to log the rehabilitation information with structured formats.

B. Personal Health Records

The Health Level Seven (HL7) provides standards for interoperability that improve care delivery, optimize workflow, reduce ambiguity, and enhance knowledge transfer among all stakeholders, including healthcare providers, government agencies, vendors, and patients [3]. The HL7 has been broadly acknowledged as healthcare data exchange standards [4].

The personal health record (PHR) is extensively utilized around the world. The PHR mainly logs the generic examination, diagnosis, treatment, and routine health records of by personal. That is, physicians and patients can record data at the same time and physicians can observe the latest diagnosis as well as treatment information from PHR. There

are many operational practices for the PHR in England. For example, one surgery allows patients to take away their records from a universal serial bus (USB) memory stick or a compact disk (CD). Patients in some practices can directly insert health data such as blood pressure (BP) and peak flow into their PHR [5].

C. Social Networks

As some researchers said that online community is the "next generation." and the social networks will strengthen the collaborative nature of the Internet[6][7][8]. Such an illustration shows the importance of the social networking in our daily life. Hence, it is necessary to effectively utilize the characteristics of the social networks. The social networks, such as Plurk [9], Twitter [10], Myspace [11], and Facebook [12], are popular in the Internet and quickly extended to diverse ages. In addition, many users play entertainment games in the Internet. Therefore, it is necessary to create an environment to attract users to utilize the SGs and to minimize the constraints of the rehabilitation time and space.

D. Framework Review

The framework review can be divided into two parts: the SGs, the AR, and the PHR. Up to the SGs framework, the most popular social networking framework is Facebook. It is executable on the Internet with web pages as well as supports part of the users' personal information for further developing utilization. Therefore, it might be one of the good framework candidates. Vacchetti uses the VHD++ as the AR framework in the industrial environments. The VHD++ is a component-based software development framework that supports composition of high performance, real-time, interactive, and audio-visual applications [13]. In order to make the SGs more diversified, part of the AR frameworks will be adopted. In addition, Johnston proposes a PHR framework and includes six parts such as patient-provider communication, personal health advocate, personal decision support, personal health journal, personal health monitoring and management, and personal health reminders [14]. These six parts are utilized by the PHR only. In case of combining with the SGs, the AR, and the PHR frameworks, it will be relatively useful for further reference in healthcare field. Therefore, the problem is how to propose a feasible framework to simply integrate rehabilitation SGs and record related information in the PHR via the Internet, no matter where the users play the rehabilitation SGs.

II. METHODOLOGY

This section includes four subsections to illustrate the methodologies such as the AR tool kits with open sources, the Clinical Document Architecture (CDA) adoption, social connections with Facebook, and the augmented reality serious games (ARSG) framework design.

A. AR Tool Kits with Open Sources

Several AR development tools supply source codes. The comparisons for three AR tools are described as below.

1) *ARToolKit:* It is a library set that is developed by C/C++ and supports multimedia functions. The ARToolKit can identify the multiple recognition and user-defined graphic markers. It also supports multiple platforms.
2) *NyARToolKit:* It is an enhanced version of ARToolKit with AR Java library. Its functions are similar to the ARToolKit, support virtual platforms such as Java, C#, and Android, and let developers design AR applications under diverse platforms.
3) *FLARToolKit:* It is rewritten from the NyARToolKit by Java programming language. Mainly, it supports graphic marker tracking and recognition and can interact with users in the web pages. It is not necessary for developers to setup any complicate system environment. However, it is not efficient in the recognition and vision effects.

Table I illustrates the comparison of the above three tool kits. Because Java is a cross-platform programming languages and the NyARToolKit functions are similar to the ARToolKit ones, the NyARToolKit becomes the basic development library for the proposed system. Meanwhile, the NyARToolKit is more powerful than the other tool kits, owns better image recognition capability, and supplies multiple recognition functions. Therefore, it becomes the major development platform and some SGs are developed to let patients achieve rehabilitation effects unconsciously.

TABLE I COMPARISON OF AUGMENTED REALITY TOOL SETS

Item	ARToolKit	NyARToolKit	FLARToolKet
Development environment	C/C++	Java, C#, Android	ActionScript 3.0
Vision effects	Support multimedia	Support multimedia	No available
Recognition	Multiple identification	Multiple identification	More difficult
Facility	More difficult	Moderate	Easier

B. CDA Adoption

The most popular information exchange standard for Electronic Medical Records (EMR) usage is the CDA R2 that is proposed and maintained by the HL7. The CDA adopts the HL7 developing framework and is based on HL7 reference information model (RIM) and the HL7 v3 data types. Hence the HL7 standards are chosen as the proposed framework basis. Essentially, the CDA context is persistent and based on the extensive markup language (XML) standard. The XML let the developers create their own tags and such a function is helpful for the further system establishment. Therefore, the system adopts XML technology to HL7 standard and record patient rehabilitation information inside the CDA documents. The proposed system can record the rehabilitation information after the users utilize the system. It is not only let physician understand the patients' rehabilitation state, but also let patients understand his or her latest rehabilitation states. Once rehabilitation SGs can collect the related data, it is the further step to popularize these SGs to every possible user. Therefore, the proposed framework concerns to adopt the social power of the Internet.

C. *Social Connections with Facebook*

In order to facilitate our SGs in the Internet and integrate with some social networking website such as Facebook, it is necessary to transplant the window-based SGs to the web-based SGs. The major advantage for our proposed design is to save the cost for buying SG machines and related sport equipment. The second advantage is that the users execute rehabilitation activity without any time or space constraints. That is, rehabilitation users only need to connect to the Internet with a simple low-end camera and some markers. Then the users can utilize the ARSGs to achieve the specific rehabilitation effects. Hence, it is necessary to create an appropriate framework to include diverse SGs.

Facebook provides various entertainment games. If some of them can reach the rehabilitation effects, it will be the good news for rehabilitation patients and physicians. Therefore, Facebook becomes the experimental environment and the other social networking websites will be covered later. It is feasible to facilitate the rehabilitation processes by utilizing the spread of the community pages. The social networks can be designed as a nice fundamental architecture to let diverse SGs be added on simply. Such an effective expanding strategy will break the limitation of rehabilitative SGs among social networks and achieve the popularization effects.

D. *SGs Framework Designs*

Based on the medical decision support requirements in the PHR, the user can discuss his or her rehabilitation state with his or her physicians. Meanwhile, physicians can understand and plan patients' medical care later. Hence personal health journal can store patient records and manage patient's personal medical information. The PHR can record and list patient's activity information of rehabilitation duration for further reference. Physician can also understand the rehabilitation state with related statistical graphs. At last, patients can execute the rehabilitation activities through a planned contest in the Internet with their community friends in order to increase the utilization rate among rehabilitation patients.

This research proposes a SGs framework to reach the diversity of the AR technology, in order to gain more rehabilitation functions. The SGs framework can be divided into three parts such as sensing, transformation, and outcome. The necessary processes include the camera to read the picture cards, then the converter through the image recognition to identify the picture card, and finally present the outcome on the screen. This ARSG designed to include two different SGs according to the different parts of rehabilitation.

1) *Puzzle Game:* Question and answer (Q&A) style lets the user play this SG as the following procedures. (1) The screen shows the question, (2) the user need to choose the correct card to answer this question, (3) the SG changes the question until the user answers the correct answer, (4) the system gets the picture information, (5) the system analyzes and finds the executing module, and (6) the system finally shows results on the screen.
2) *Snake Game for Hand Movements:* This SG utilizes three-axis accelerometer technology and lets the snake eat the point. This SG can train the accurate muscle movements. The procedure is (1) the system gets the data from the three-axis accelerometer, (2) the system analyzes those data, (3) the system transforms those data into rehabilitation information, and (4) the system finally shows the results on the screen.

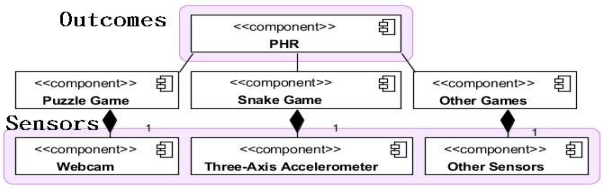


Fig. 1. Augmented reality serious game framework.

Generally, the SGs' instructions can be roughly divided into three parts, such as sensing, transformation, and outcome, as shown in Fig. 1. Hence, it is necessary to design a flexible framework, such as ARSG, to easily add diversified SGs, to categorize the SGs by distinct rehabilitative requirements, and to meet the rehabilitative goals

III. RESULTS

Several SGs have been developed and some of them are similar to the puzzle game. For example, one of the developed SGs utilizes the Q&A style to couple with the marker operations and let users observe the image which is shown at the top of the markers. Therefore, the SG can recognize the scope of the markers and read the related image files from database that is shown in Fig. 2.

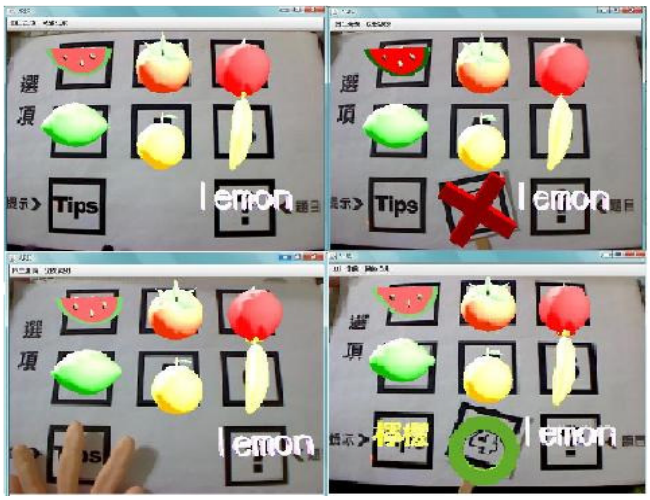


Fig. 2. Some of the screen snapshots for puzzle game.

At first, the system will display question and the question marker will show the question name. For example, question marker in Fig. 2 shows 'lemon' word and user can choose a correct answer from one of the number markers. Note that the right-top subfigure shows the screen snapshot of the incorrect answer. In case that the user has no idea to choose the correct answer, the user can use his or her hand to cover the tips marker for one second which is shown on the left-bottom subfigure and our system will open hint mode soon. Then the

camera screen will display the hint 3D object simultaneously in the right-bottom subfigure. This SG can be integrated within the ARSG framework and the ARSG integrating procedure is also defined. Therefore, the ARSG framework with integrating other SGs can achieve the multiple purposed goals for rehabilitation through the Internet.

IV. Discussion

Three subsections, such as marker recognition, security concerns, and secondary injury, are illustrated as below.

A. *Marker Recognition*

Up to the graphic tags, the modeling images sometimes cannot be effectively recognized by the developed system. That is, some tags will be affected by various rehabilitation environment factors such as marker size, marker color, background image, and lights. These effects affect the recognition level. The experimental results are listed as below.

1) Marker Size: The size is tested from 0.5 cm^2 to 6 cm^2 and the results are shown in Table II. Note that the marker with 0.5 cm^2 (the right top one) is not recognizable.

2) Marker Color: The comparison results of six cases are shown in Table II. In addition, the color image test is executed and put in the middle of the marker. It proves that the system can recognize the darker markers.

3) Lights: The light is a key to affect the recognition. Some experimental results are listed in Table III.

TABLE II Size and Light Experimental Results

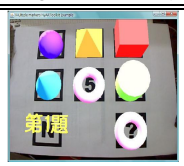
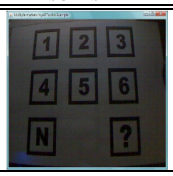
Execution screen			
Outcome	0.5 cm^2 is unrecognizable.	Recognizable	Unrecognizable

TABLE III Marker Color Comparison

Appearance Description		Recognizable
Frame color	Background color	
Black	White	Yes
Yellow	White	No
Black	Yellow	Yes
Light color	White	No
Gradient color	White	No
Color	White	Only recognize the dark parts

B. *Security Concerns*

Security and privacy are very important considerations in the healthcare field [15]. The PHR security architecture is not so reliable that the ARSG framework has to adopt other security technologies to achieve better data protection soon.

C. *Secondary Injury*

Because the rehabilitation effects need more evaluation, its effects might be varied by people. It is possible for patients to enjoy these SGs for a long time and damage part of their bodies again. Hence, it is necessary for patients to avoid secondary injury by playing the SGs. Furthermore, it is another research target for deciding whether the rehabilitation SG system needs physicians to further monitor.

V. Conclusion

The proposed framework for integrating SGs facilitates the patients to execute rehabilitative activities without any geographical or time limitations. Meanwhile, it couples with social networks for rapid spread and tries to let more people understand the rehabilitation capabilities. Up to the system development considerations, it is necessary for AR developers to familiar the 3D modeling with art basis. At last, the proposed ARSG framework and SGs are not limited by hardware and can be easily accessed in the Internet.

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References

[1] The American Telemedicine Association [Online]. Available: http://www.medterms.com/script/main/art.asp?articlekey=33620

[2] R. T. Azuma, "A Survey of Augmented Reality," in *Presence: Teleoperators and Virtual Environments,* 6(4): 355-385, August 1997.

[3] Health Level Seven International [Online]. Available: http://www.hl7.org/about/index.cfm?ref=nav

[4] P. H. Cheng, S. J. Chen, and J. S. Lai, "Evolution and Integration of Medical Laboratory Information System in an Asia National Medical Center," *IEICE Trans. Communications*, E92-B(2): 379-386, Feb. 2009.

[5] B. Fisher, R. Fitton, C. Poirier, and D. Stables, "Patient Record Access – The Time Has Come," *British J. of General Practice*, 57(539): 507-511, June 2007

[6] K. Jordan, J. Hauser, and S. Foster, "Augmented Social Network: Building Identity and Trust into the Next-Generation Internet," *First Monday,* 8(8), 2003.

[7] J. Breslin and S. Decker, "The Future of Social Networks on the Internet: The Need for Semantics", *IEEE Internet Computing*, 11(6): 86-90, 2007.

[8] L. Sørensen and K. E. Skouby, "Next Generation Social Networks - Elicitation of User Requirements," In Proc. of the IEEE Int'l Symposium on Personal, Indoor and Mobile Radio Communications, pp. 1-5, 2008

[9] Plurk [Online]. Available: http://www.plurk.com/t/Taiwan#hot

[10] Twitter [Online]. Available: http://twitter.com/

[11] Myspace [Online]. Available: http://www.myspace.com/

[12] Facebook [Online]. Available: http://zh-tw.facebook.com/

[13] L. Vacchetti, V. Lepetit, M. Ponder, G. Papagiannakis, D. Thalmann, N. Magnenat-Thalmann, and P. Fua, "Stable Real-time AR Framework for Training and Planning in Industrial Environments," In S. Ong and A. Nee, editors, *Virtual and Augmented Reality Applications in Manufacturing*, pp. 129-146. Springer-Verlag, 2004.

[14] D. Johnston, D. Kaelber, E. C. Pan, D. Bu, S. Shah, J. M. Hook, and B. Middleton, "A Framework and Approach for Assessing the Value of Personal Health Records (PHRs)," *AMIA Annu Symp Proc.*, pp. 374-378, Oct. 2007.

[15] M. J. Su, H. S. Chen, C. Y. Yang, S. J. Chen, R. Chen, W. J. Lee, P. H. Cheng, P. K. Yip, H. M. Liu , F. P. Lai, D. Racoceanu, "Diagnostic Decision Support by Intelligent Medical Image Retrieval with Electronic Medical Record for Dementia Treatment Enhancement," In *Medical Imaging Technology,* 25(5): 350-355, Nov. 2007.