The Electronic Library

Get lost in the library?: An innovative application of augmented reality and indoor positioning technologies

Tien-Chi Huang Yu Shu Ting-Chieh Yeh Pei-Ya Zeng

Received 29 August 2014
Revised 24 November 2014
Accepted 31 December 2014

Get lost in the library?

An innovative application of augmented reality and indoor positioning technologies

Tien-Chi Huang
National Taichung University of Science and Technology, Taichung, Taiwan

Yu Shu
National Changhua University of Education, Changhua, Taiwan, and

Ting-Chieh Yeh and Pei-Ya Zeng
National Taichung University of Science and Technology, Taichung, Taiwan

Abstract

Purpose – This paper aims to identify ways to establish an information system to aid users to enhance the effectiveness of self-regulated learning and solve the problem of learning domain unawareness. Many libraries are spacious and with a rich collection of books, the problem a newcomer may encounter in the wide library is spatial unawareness. In addition, people new to a particular field of study often encounter the problem of learning domain unawareness.

Design/methodology/approach – This paper presents an overview of self-regulated learning theory first. We realize the essential principles of self-regulated learning model in the library and developed a learning system that utilizes the concept of combining mobile augmented reality (AR), indoor navigation and data mining algorithms.

Findings – The proposed NO Donkey E-learning (NODE) system utilizes AR and innovative indoor positioning technology to fulfil the goal of navigation inside a library and solve the problems of spatial and learning domain unawareness. On the one hand, the system allows peers to communicate asynchronously to create a cloud-based information sharing community; the dual-track terminal (the website and the app interfaces) in the system could provide both educational functionalities and mobility for readers. On the other hand, AR navigation function integrates the information of reading paths, the real-space locations, real-time dynamic information, book introductions and readers' comments to help readers have access to the topic-related books efficiently.

Practical implications – We found that although the library provides the floor plan and signs, such passive and fixed indication may cause spatial unawareness. People need system to show the bookshelf location and dynamic direction indicators when they walk in the wide library. However, most existing library information systems only provide readers with the function of book search, including which floor the book is on, call number and check-out status. In this sense, we propose that self-regulated learning theory integrated the new innovation technology is the solution for the above issues.

Originality/value – The system developed in this study, while viewing the real scenes inside the library through camera lens, provides related virtual educational information services and learning paths on screen and guides the public to do systematic self-regulated learning. With the functions of the "learning topic" and "knowledge sharing", the learning system promotes the general public to self-monitor their learning progress and to use the sharing mechanism as the system structure to solve

The Electronic Library
Vol. 34 No. 1, 2016
pp. 99-115

0264-0473
DOI 10.1108/EL-08-2014-0148

the two main problems of spatial unawareness and domain unawareness in learning in libraries, creating a truly innovative people-centred library information system.

Keywords Library services, Self managed learning, Information services, Knowledge sharing, E-learning

Paper type Research paper

Introduction

With the vigorous development of the Internet and information technology, Web search engines are gradually replacing traditional methods of information searching, but they cannot completely replace libraries (Huang, 2015). According to the statistics released by the Ministry of Education in Taiwan for books checked out by high school students from 2007 to 2011, the number of checkouts increased by nearly 50 per cent compared to that five years ago and the growth rate is around 9.0 per cent within a year. The number of books checked out increased by 21.9 per cent within a year and increased by 81.2 per cent compared to that of five years ago. By the constant positive growth, it is clear that books are still the main source of knowledge for the general public.

The National Library of Public Information, planned and established two years ago by the Ministry of Education, Republic of China (Taiwan), is one of the three national libraries in Taiwan. It collects, organizes and provides a repository of various book and digital resources and so on. Figure 1 shows a plan view of the fourth floor of the library with a total floor area of 41,797 square meters. Although a spacious environment allows a library to have a great amount of book storage, the problem of spatial unawareness for new readers exists (Gouveia and Gouveia, 2002). *Spatial unawareness* refers to the situation when readers fail to find where and how to get to target resources effectively with the current hints provided by libraries. The existing indicator boards, either hanging on the ceiling or the wall, have little functionality for readers, as these designs are not individualized. The readers must be on site to find, according to their individual needs, whether they are going in the right direction or are in the correct area. They may also be confused about their own location and the relative location between their resource targets and them. It could be said that readers actually need “personal direction” rather than “public direction”. On the matter of how to fulfil personalized navigation, this study suggests the use of augmented reality (AR) technology to develop a click-and-mortar information technology (IT) system to provide customized in-door navigation functions developed with the proposed technique on the readers’ smart devices (Huang, 2014).

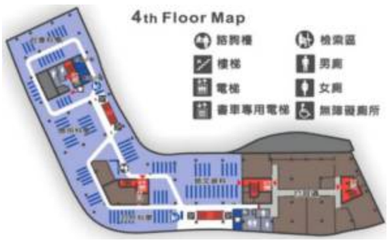

Figure 1.
Plan view of fourth floor of the National Library of Public Information

In addition, most existing library information systems only assist users in searching for a specific book, as the information it provides are simply the floor and the call number of the item the reader is looking for. However, these services failed to satisfy the other kind of readers who are in the library for discovery, rather than to seek a specific item. Discovery-oriented readers may only have vague ideas in mind of an issue or topic they are seeking, rather than a specific book or magazine that they want to obtain. They have to play the "trial and error" game in the searching system to get proper keywords to find which resources will serve to satisfy their curiosity about an issue, which is called the phenomenon of *learning domain unawareness*. Solving the problem of learning domain unawareness is the second purpose of this study. To solve this problem, this study adopts the concept of learning topics and includes the functions of the exchange of knowledge, the categorization of learning topics and learning logs to provide readers with topic resource guidance called "reading path" and "learning path". The ideas of *learning path* (LP) and *reading path* were derived from social constructivism, which are a representation of collective experiences.

This study postulates that readers are different forms of learners and that they could be encouraged to achieve in different domains, even if they are not students within a specific departmental school (Huang and Chen, 2013). In this sense, the proposed system further adopts the theory of self-regulated learning to design the functions in it, which will provide a system to satisfy readers who want to learn in the library and will help readers learn better. Therefore, the NO Donkey E-learning (NODE) system developed in this study attempts to solve the issues of spatial unawareness and learning domain unawareness in physical libraries and further, using collective intelligence, to guide the public to do systematic self-regulated learning in the library.

Theoretical background

Learning with AR in library context

Deciding which technologies can best be used to improve the efficiency of book searching should be addressed. The advantage of AR technology is to allow the integration of virtual information into the real environment. Originally, objects by themselves in the real environment do not have learning essence, but when the virtual objects of AR are attached to the real objects, it effectively and massively enriches the experience of that environment (Dunleavy *et al.*, 2008).

The question becomes how to effectively use AR technology to develop information systems in libraries. Over the past two decades, clues can be found about the application of IT in libraries in studies conducted by Fitzmaurice (1993); he developed the Chameleon prototype and proposed the concept of the *Computer-Augmented Library*. The Chameleon prototype aims to improve the efficiency of book searching via augmented information. The traditional book search is nothing more than the following two steps:

(1) looking up the call number in the library information system; and

(2) identifying the placement of books within the library based on the call number.

The Chameleon prototype integrates the above two steps, and uses sensors built onto the shelves and books to clearly point out books on the shelves that match the search criteria. The prototype shows the dawn of research into computer-augmented applications in libraries.

In recent years, AR technology has been widely applied in library systems. Brinkman and Brinkman (2013) used AR to propose a set of identification technology, ShelvAR, to help librarians arrange books quickly. ShelvAR can identify the icon tag on the back of books and then automatically point out the right and wrong arrangement of books to help people quickly identify if a large number of books is arranged correctly. In such a way, the time required for human identification by eye and human error is reduced. Chen and Tsai (2012) further integrated AR technology and library learning with elementary school students who were taught how to correctly use the library via AR interaction. Through 3D characters and story-based games, ARLIS taught them how to find books and learn in the physical library. The study found that the effectiveness of ARLIS is identical to the introduction by real library staff, thus effectively allows library management to reduce the required manpower when providing introductory sessions.

Traditional application of an AR teaching environment usually makes use of computers and webcams, but this is extremely inconvenient to users because the computers usually cannot be taken with them. More recently, due to the vigorous development of mobile intelligent terminals and the gradual increase in importance of mobile learning (Huang and Chiu, 2015), it is possible to develop AR systems on mobile devices (Martin *et al.*, 2011).To allow users to be able to operate the system anytime and anywhere when they visit libraries, the system is constructed for smartphones and tablets. Smartphone penetration is currently very high, and with its features of positioning systems and wireless connection, the smartphone can effectively combine virtual information with the real environment and create a ubiquitous learning environment (Broll *et al.*, 2008; Chen and Huang, 2012). This type of AR system is also known as Mobile AR (Chen *et al.*, 2013; Feng *et al.*, 2008).

Today, there are many educational information systems developed through Mobile AR models, such as the simulation, with an Android tablet, of the scene of the campus within a 12 km radius of the Fukushima nuclear power plant the first day after its nuclear explosion. Research found that learners' attitudes towards nuclear issues were significantly correlated with their exposure to AR presentations (Chang *et al.*, 2012). Klopfer and Squire (2008), on the other hand, allowed students to experience scientific phenomena which cannot be experienced in real life through AR. Liu *et al.* (2007) integrated many types of AR systems to allow students to see virtual solar systems and the process of photosynthesis of plants on classroom desks. According to Di Serio *et al.* (2013), the research on art education among high school students proved that AR enhances learners' motivation. The first stage is accomplished through slides, a traditional teaching method and the second stage is for students to proceed with self-regulated learning through AR equipment. This shows that AR technology is quite effective when applied in education, yet there has not been a Mobile AR system applied in the development of a library system. Hence, in this study, more information is provided to the library learning environment through the integration of physical and virtual resources. The system allows learners to quickly find book locations, information, reviews and critiques displayed on their own handheld devices. Virtual information customized by learners can be presented at different facilities and locations in the libraries to provide learners with efficient and convenient access to information services.

Self-regulated learning

According to Knowles (1975), the self-directed learner must decide the need for self-learning, establish learning objectives and search for learning resources with or without the help of others, execute appropriate learning strategies and be able to evaluate learning effectiveness. Therefore, self-regulated learning is a learning process, emphasizing voluntary and autonomous learning (Knowles, 1975).

Although past studies applied information technologies to diagnose learning status (Huang *et al.*, 2014), the authors argue that learning begins with the contexts that learners own and control their learning status by themselves. This study refers to the characteristics of self-regulated learners and the ability to perform self-directed learning proposed by Knowles (1975). The essence of self-directed learning and self-regulated learning is a topic that has received increasing attention and has been one of the main objectives of formal education set by researchers in the past. The goal is to train students to retain their self-learning ability after graduating from schools and to continue to perform self-regulated learning throughout their life (Boekaerts, 1997). In recent years, many researchers have explored the effect of self-regulated learning in the learning process (Chang *et al.*, 2013; Wang, 2011; You and Kang, 2014). However, most of these studies investigated self-regulated learning behaviours limited to e-learning or online learning contexts rather than in informal physical learning environments, such as libraries and museums. In view of this fact, the authors attempt to develop an information system to assist learners to carry out their self-regulated learning in libraries.

Social constructivism

Social constructivism referred to in this study is proposed by Vygotsky who emphasizes the autonomy of learners (Baker and Piburn, 1997), as well as the ability to integrate old knowledge with new knowledge in group learning activities to then analyse and adopt the meaning of knowledge. When there is cognitive conflict, the two ideas are compared and analysed so that learners are able to gain a clearer understanding of the information (Duffy and Jonassen, 1992).

Wang (2014) proposed utilizing the collaboration and interaction obtained with wikis, along with social constructivism, to promote the development of language and social interaction. In addition, it is proved that allowing learners to interact with each other can effectively improve the development of the collaborative learning environment (Behzadan *et al.*, 2011).

Nevertheless, many modern libraries are still for personal reading only. The acquired knowledge is hence limited to individuals. Individually acquired knowledge cannot be circulated and shared, so learners largely depend on a self-learning experience. Especially for beginners, who have to take a lot of time to consider and learn what resources could meet their needs. In this study, the authors developed the NODE system to allow reading information to be interactively shared through association rules by extraction and comment mechanisms to enhance the effect of self-regulated learning.

Technological background

Augmented reality

AR is a technology combining the virtual environment and the real world. Through this technology, the real environment seen by human eyes is integrated with the virtual information displayed and then human eyes are able to see a more diversified world. Among the multiple types of AR – such as headset types, handheld types, space projectors and computer screens – the headset type and space projectors are overly expensive and, therefore, unsuitable to be applied in library environments, so they are excluded in this study. Although the price of computer screens has become more reasonable, considering their limited mobility and the fact that they cannot be carried around, they are not a suitable device to be used for the public to perform self-regulated learning anytime, anywhere (Bimber and Raskar, 2005). The most commonly used AR systems on mobile devices are usually divided into two types:

(1) Identify objects, picture cards, images and other media in the real environment and display them on the screen of a mobile device so that the virtual environment can interact with real objects.

(2) Display virtual information directly on the screen of a mobile device so that objects originally without any special meaning are attached with additional information. Commonly attached information includes store information, locations of public equipment and so on.

Association rules extracting to create the reading paths

Inspired by social constructivism, this study believed that collective reading records are not just a collection or display of individual records. These data imply useful educational value minded by algorithms and technologies (Liang and Huang, 2014). This study proposes an algorithm, using a great deal of reading records to organize and generalize a set of learning rules. The learning rules are referred to as the "learning paths" in this study.

To generate rules, circulation and patron statistics in one month were adopted to calculate the percentage of each category of books borrowed. The percentage higher than 50 per cent indicated the main focus of a reading topic in that month. After obtaining the readers' topic of the month, through the data mining technology a priori association rules algorithm, the degree of association of each book with the next book read can be calculated and further results in which book will be recorded as the order in a reading topic. The system keeps track of the reading status continuously. If the statistics show that the learner read books in the "technology-website learning" category for two months, the system can analyse whether there is a second or third book checked out in the two months; if any, the books can then be used as primitive data for association analysis. Next, the system will conduct analysis on other learners based on the same topic, collect a large amount of primitive data for association analysis and connect similar rules together to come up with a complete set of learning topics and learning paths.

After the system obtains the above learning path, it saves the path to the learning topic for other learners' reference. To obtain a longer learning path, more association rules should be analysed or more data should be collected for analysis. With the accumulation of time, learners' reading information continues to increase and, therefore, association analysis can be conducted from time to time so that the content of a learning topic is constantly optimized. This study summarizes the experiences of past learners through association analysis and treats many learners' order of reading as resources that can help other learners to increase the learning effectiveness when they first start.

The a priori association rules algorithm used in this study is summarized as shown below:

A priori (BR, μ)
  $L_1 \leftarrow$ {The large 1-itemsets of books collecting from the DB}
  $j \leftarrow 2$
    while $L_{j-1} \neq \varnothing$
      $C_j \leftarrow \{a \cup \{b\} \mid a \in L_{j-1} \wedge b \in \cup L_{j-1} \wedge b \notin a\}$
      for transactions $t \in$ BR
        $C_t \leftarrow \{c \mid c \in C_j \wedge c \subseteq t\}$
        for candidates $c \in C_t$
          $support[c] \leftarrow support[c] + 1$
      $L_j \leftarrow \{c \mid c \in C_j \wedge support\,[c] \geq \mu\}$
      $j \leftarrow j + 1$
    return $\bigcup_j L_j$
BR → Book Borrowing Records
μ → The minimum support number of qualified
t ransactions → Each data from Database

L_1 refers to the data to be analysed by the algorithm and they are the primitive information mentioned in earlier paragraphs. Each item includes k itemsets, referred to as k-itemset. The algorithm starts analysis from 1-itemset and generates 2-itemset, 3-itemset until no larger itemset can be found. When the ultimate large-item is defined, the association rules conforming to the minimum confidence can be generated according to each item. When the number of rules generated is more than enough so that there are correlations between the rules, a LP is formed.

Indoor positioning, navigation and cost analysis. Although global position system is widely applied in positioning, it is not applicable to indoor positioning due to the impact of obstacles, such as walls or building infrastructure, blocking satellite signals. Hence, the technology and application of indoor positioning has only gradually caught the public's attention (Riaz *et al.*, 2014; Woo *et al.*, 2011). Even though there has been much literature regarding the research and development of indoor positioning – fingerprint-based Wi-Fi positioning systems, Bluetooth 4.0 signals and environmental perception, for instance – there has not been an indoor positioning system that can achieve rapid setting and precise positioning at the same time.

To address the issue and achieve the purpose of this study, we adopted the BuildNGO technology, developed by SAILS Technology (www.sailstech.com), with which indoor environment positioning can be achieved using smartphones. As shown in Figure 2, BuildNGO only needs to detect signals from Wi-Fi access points, Bluetooth transmitters or Beacons – equipment developed by SAILS Technology – on site and with the building floor plan, indoor positioning can be processed and the positioning information or navigation path can be displayed on handheld devices. Learners can find specific books with such a navigation function effortlessly and quickly in a spacious library; this is especially a huge aid for learners who are in the library for the first time.

This study uses four different kinds of signal sources, and each source is processed with four pieces of equipment for indoor positioning comparison (as shown in Table I). It is shown from the following table that using four Beacons for indoor positioning results in a positioning accuracy of 50 m^2; which can be obtained at low cost, yet still provides for the most extensive range of positioning accuracy. According to the result,

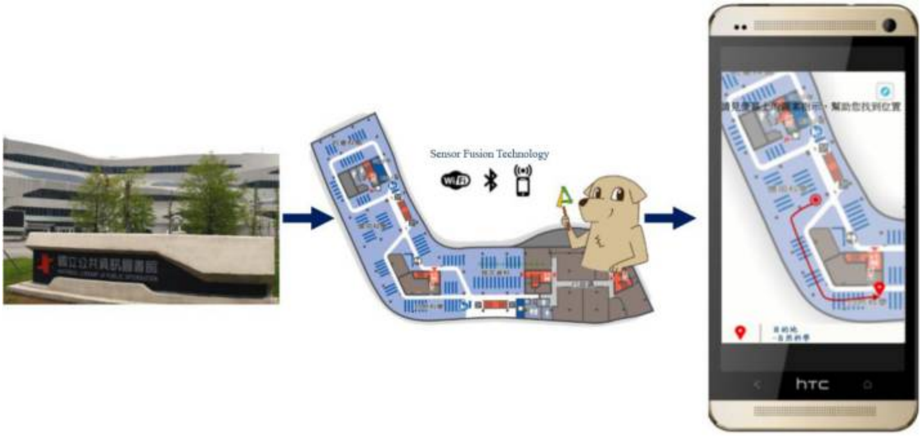

Figure 2.
Illustration of BuildNGO technology

Table I.
The cost comparison among four indoor positioning signal sources

Signal source	No.	Positioning range (m^2)	Cost USD
Beacon (BLE4.0)	4	50	9.7
Wi-Fi	4	36	16.2
RFID (Ting *et al.*, 2011)	4	9	26
ZIGBEE (Chen *et al.*, 2009)	4	9	32.4

this system uses the Beacon equipment as an indoor positioning product to assist in this study. Beacon can accept multiple Wi-Fi signals within an area; the signals are processed by algorithms and send the results to handheld devices for further processing. All national public libraries in Taiwan already have Wi-Fi access points, so the cost for the Beacon equipment is the only constructional cost to achieve indoor positioning.

System architecture and development

The proposed system named NODE (NO Donkey E-learning) consists of four layers, including the application layer, the module layer, the agent-based layer and the repository layer, as shown in Figure 3. The system design adopts modular design. Agent-based technology actively collects environment information and user learning logs, sends the data to each module for functional operations and finally presents the results on the application layer. Elements of each layer and how each layer works will be described in detail in the following section.

Repository layer. The AR object position stores locations of all AR objects in the library, such as the locations of books and audio resources or objects created by members, which need to be stored additionally. When the AR navigation function is activated, detailed information in this repository needs to be accessed. The system saves library members' check-out records in borrowing records; these records are mainly used for data mining of analysis of learning paths. The e-portfolio repository stores basic information when library members first applied for library membership and their learning logs later in the library, including the progress of learning topics, reviews of and comments about books and learning paths created and collected. Functions of "reading path" and "learning path" will be described in detail in later sections of system demonstration.

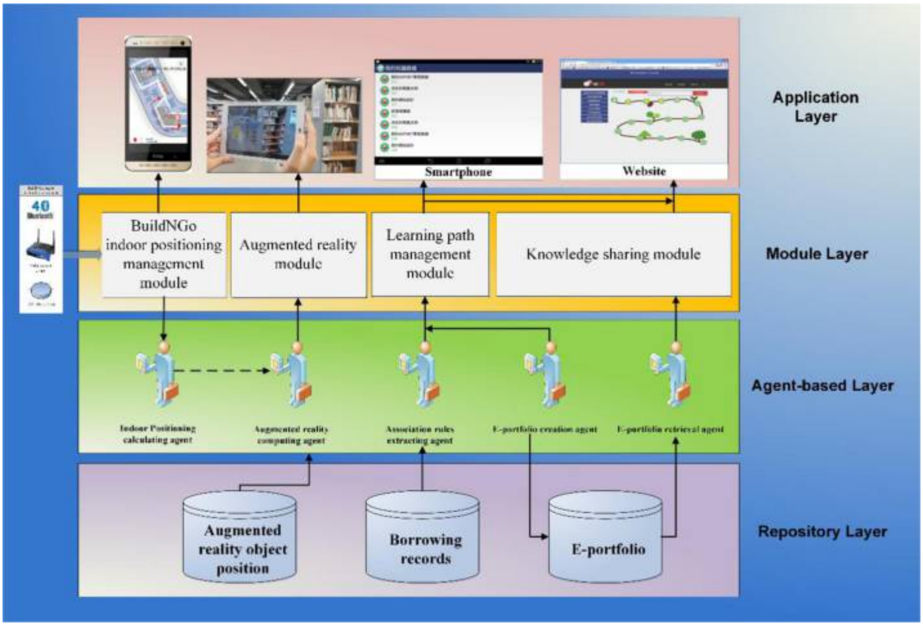

Figure 3.
NODE system architecture

Agent-based layer. When the user activates the AR navigation function, the BuildNGO indoor positioning calculating agent calculates the absolute position of the user; the position of an AR object is derived from the AR object position. The above data are transmitted to the AR computing agent for further calculation. The positions of the user and the AR object are input; the Euclidean distance, angle and orientation between the two points are then calculated and transmitted to the upper layer AR module to process accurate AR navigation.

Association rules extracting agent is used to calculate the association rules in borrowing records. As stated in the above section, gradual rules of learning are obtained from calculated association rules and are then integrated and become a LP of a specific field. This study classifies numerous paths and they are collectively referred to as "learning topics". "Learning topics" provide beginners with a step-by-step approach in learning, and help them reduce the effort to find books that are irrelevant or not suitable for the level of difficulty. The e-portfolio creation agent is responsible for recording the user's learning logs and LPs and stores them in the e-portfolio repository. When the user has made certain progress in learning, their learning logs will be recorded through the agent. When the user wishes to create their own LP, the same agent is also responsible. Information in the e-portfolio repository is used in data mining, learning logs and knowledge sharing. The above information is read by the e-portfolio retrieval agent and it then provides the LP management module and knowledge-sharing module with the information for further processing.

Module layer. The BuildNGO indoor positioning management module utilizes wireless signals of Bluetooth 4.0, Wi-Fi access point and BuildNGO magic node in the environment to calculate the user's position in the library. The AR module allows the user to see the positions of AR virtual objects in the real space through the smartphone camera. To compute the relative positions of AR objects and the user, data transmission between the above-mentioned indoor positioning calculating agent and AR computing agent is required so that the positions of virtual objects can be displayed on the smartphone.

The LP management module is responsible for the management of learning topics and learning logs. When the user wishes to learn a certain field, a correspondent "reading path" will be obtained through the association rules extracting agent. When the user wishes to record their learning logs, the progress is recorded by the e-portfolio creation agent.

The knowledge-sharing module is responsible for the management of LPs. The "knowledge sharing" function provided by this study includes creating, collecting and executing paths. As the user creates a LP, the e-portfolio creation agent records the LP into the e-portfolio repository. When the user wishes to manage LPs on website platforms or follow others' paths through a mobile device, the path information is obtained through the e-portfolio retrieval agent.

System demonstration and learning model

Solutions to learning domain unawareness: reading path and learning path. To solve the problem of learning domain unawareness and to assist learners in establishing a complete library learning model, this study creates two sets of "learning paths" which are the personalized LP created by learners themselves, the "reading path" formed by big data on checkouts and the "dual-track terminals" respectively.

Reading path: automatically recommended. This study uses data mining technology-association rule analysis to provide readers references in the form of converted reading paths (Figure 4) in a progressive manner. The reading paths are formed with nodes which are automatically provided books. Therefore, to discover information in one domain, the readers could access the interface of "reading topics" to choose a suitable topic and follow the reading path (book nodes) provided in this function.

Learning path: personalized project and record. The LP (Figure 5), consists of learning nodes, and is different from the reading path which is automatically created with the big data of checkouts, as the LP is established by the readers themselves. Each reader can, according to their own learning needs, customize personal but public learning paths (PLPs) known as the customized learning path (CLP) or collect LPs created by other readers, known as the PLP in the LP list (Figure 6).

The constituent elements of PLP are learning nodes. In this system, readers can create three different types of learning nodes, including book information, multimedia information and a sudden inspiration, according to their learning needs. Book information includes various types of books, newspapers and magazines. Multimedia information includes various video or musical disk resources in the library.

Dual-track terminals: NODE app and NODE website. Considering the convenience of using the proposed system, this study establishes two use terminals, which are the NODE website and the NODE app. The NODE website is a personal-centred cloud system for readers. It allows readers, after login, to create CLPs, or search and collect PLPs, anywhere with equipment that can access the Internet, including tablets, laptops and desktop computers. Readers can also create personal comments, reviews and record their reading progress for certain books in the reading path on the NODE website to

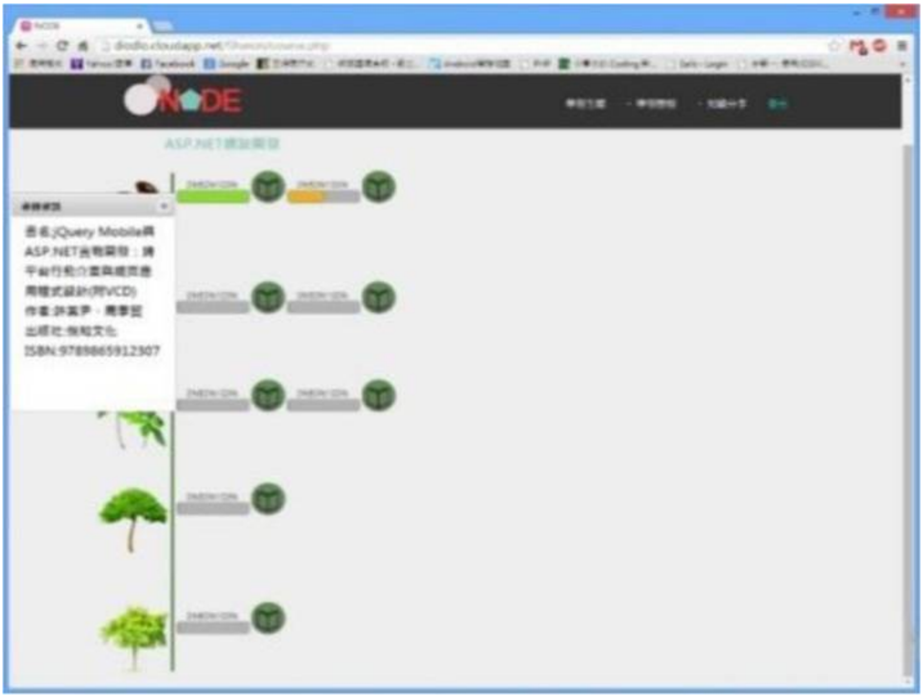

Figure 4. Progress of reading and comments and reviews of books in reading path

achieve self-regulated learning. The NODE app, on the other hand, allows readers to add nodes, adjust the order of nodes in CLPs and view their reading progress of recommended reading lists in reading paths. All data are stored in the cloud-based storage. As long as the user logs into her/his own account, she/he is able to access her/his own learning records using different devices.

Mobile AR navigation for solving spatial unawareness. This study sets up the AR navigation function. When readers choose the reading path and personalized LP they want and click on the nodes of books, inspiration, or multimedia resources in the paths, the NODE app will show the bookshelf location and dynamic direction indicators (Figure 7). When readers click on AR objects, the detailed introduction and comments of other readers about the book will be shown. In summary, the AR navigation function integrates the information of reading paths, the real-space locations, real-time dynamic information, book introductions and readers' comments to help readers have access to the topic-related books efficiently.

Library self-regulated learning model. This research adopts the concept of self-regulated learning proposed by Zimmerman *et al.* (1996) and the concept of resource management strategies proposed by Pintrich *et al.* (1989) to construct the "self-regulated learning model in libraries", as shown in Figure 8. The inner circulation is the learning circulation based on theory; the outer circulation is the learning circulation which users undergo when they use the NODE system, which can assist readers in goal setting, strategies planning, and implementation and monitoring of strategies.

Figure 5.
Learning path
(NODE website)

Figure 6.
Learning path list
(NODE app)

Figure 7. Mobile AR navigation

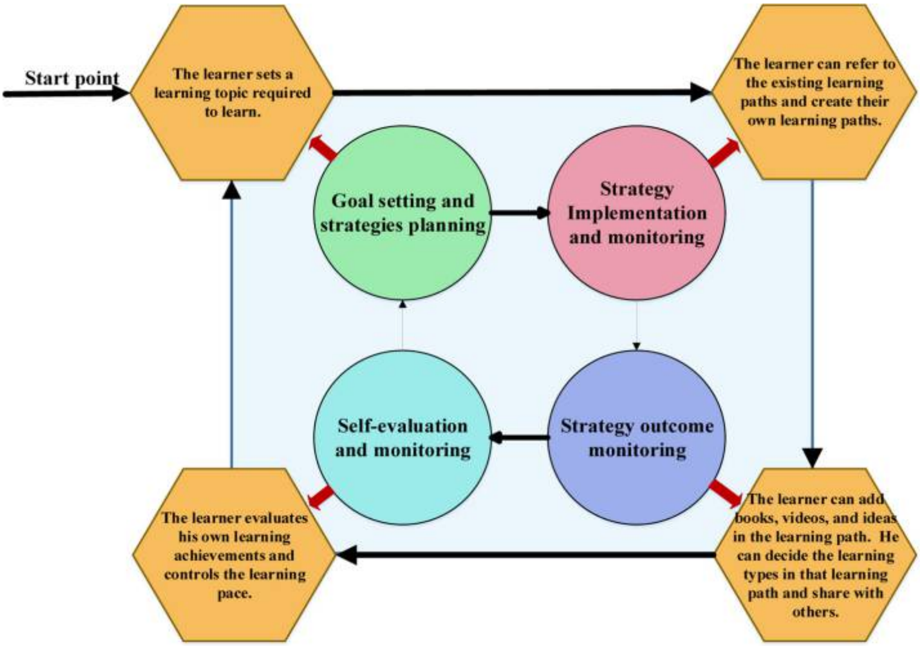

Figure 8. The proposed library self-regulated learning model

Using scenarios

The specific scenario of the library learning model created in this study is illustrated in Figure 9. With the learning model (Figure 9) and system proposed by this study, readers can choose the reading topics and follow the reading paths or the personalized LPs. With the AR navigation function in the system, readers can follow the path to systematically read data, literature and books to conduct self-learning.

Figure 9.
The whole operation procedure of NODE system

If readers already have plans for the topics to be explored, they can create their own CLPs or they can adopt PLPs created by other readers. Readers can select the LP they wish to follow with their handheld device in the library. Similar to the use of the reading path, readers can select nodes in the LP that they are interested in and the AR navigation function will assist in guiding them to the location. Hence, the time readers spend in the library to look for resources is reduced and the effect of self-regulated learning is achieved.

Conclusions and future work

The learning system developed in this study combines mobile AR and indoor navigation to provide the general public with a more convenient and intuitive book search process, thus achieving the National Public Libraries' goal of providing click-and-mortar information services. The NODE system encourages the general public to self-regulate their learning progress and to use the sharing mechanism as the system structure to solve the two main problems of spatial unawareness and domain unawareness in physical libraries. Ultimately, the purpose of this system is not to replace traditional library information systems, but to provide an innovative, reader-centred information service for the physical library.

The authors hope that the system can be gradually expanded to other national libraries and their subordinate, small- or medium-sized libraries. Also, in the future, additional records will be gathered to provide for the optimization of learning topics and the utilization of cloud services can hopefully promote knowledge sharing among different citizens in different cities. Moreover, learning resources provided by modern libraries are more diverse; therefore, in the future, the learning type of the knowledge nodes in the system will be expanded so that learners can fully use the resources of libraries to achieve the purpose of learning. In the future, along with the popularization of e-book format and its contribution to e-learning, the authors will attempt to integrate the proposed system and learning model with e-books applied to the field of digital libraries. Perhaps an important area for future research in the years to come will be in the refinement of approaches to the analysis of reading behaviours (Huang and Liang, 2015).

Despite its contributions, this study has certain limitations. First, this is not an empirical research; therefore, we have not made statistical analyses based on user satisfaction, self-regulated learning performance or the usability of the proposed system. Moreover, because this study mainly focuses on system design and development, user privacy and data security issues have not been considered. Specifically, although the learning information is assumed as public information in this study, a personal information protection mechanism should be created to counter the problems of user privacy and data security. The limitations of this study highlight the need for future research to investigate many of the above issues and, in particular, plan to investigate the effectiveness and usability of the proposed system.

Conflict of interest: The authors declare that there is no conflict of interests regarding the publication of this paper.

References

Baker, D.R. and Piburn, M.D. (1997), *Constructing Science in Middle and Secondary School e-classrooms*, Allyn and Bacon, Boston, MA.

Behzadan, A.H., Iqbal, A. and Kamat, V.R. (2011), "A collaborative augmented reality based modeling environment for construction engineering and management education", *Simulation Conference (WSC), Proceedings of the 2011 Winter Conference, Phoenix, Arizona,* pp. 3568-3576.

Bimber, O. and Raskar, R. (2005), "Spatial augmented reality: merging real and virtual worlds", *Scientist*, Vol. 6 No. 8, pp. 41-58.

Boekaerts, M. (1997), "Self-regulated learning: a new concept embraced by researchers, policy makers, educators, teachers and students", *Learning and Instruction*, Vol. 7 No. 2, pp. 161-186.

Brinkman, B. and Brinkman, S. (2013), "AR in the library: a pilot study of multi-target acquisition usability", *IEEE International Symposium on Mixed and Augmented Reality (ISMAR), Adelaide*, 1-4 October.

Broll, W., Lindt, I., Herbst, I., Ohlenburg, J., Braun, A.K. and Wetzel, R. (2008), "Toward next-gen mobile AR games", *IEEE Computer Graphics and Applications*, Vol. 28 No. 4, pp. 40-48.

Chang, C.C., Tseng, K.H., Liang, C. and Liao, Y.M. (2013), "Constructing and evaluating online goal-setting mechanisms in web-based portfolio assessment system for facilitating self-regulated learning", *Computers & Education*, Vol. 69 No. 11, pp. 237-249.

Chang, H.Y., Wu, H.K. and Hsu, Y.S. (2012), "Integrating a mobile augmented reality activity to contextualize student learning of a socioscientific issue", *British Journal of Educational Technology*, Vol. 44 No. 3, pp. 95-99.

Chen, C.C. and Huang, T.C. (2012), "Learning in a u-Museum: developing a context-aware ubiquitous learning environment", *Computers & Education*, Vol. 59 No. 3, pp. 873-883.

Chen, C.M. and Tsai, Y.N. (2012), "Interactive augmented reality system for enhancing library instruction in elementary schools", *Computers & Education*, Vol. 59 No. 2, pp. 638-652.

Chen, D.R., Chen, M.Y., Huang, T.C. and Hsu, W.P. (2013), "Developing a mobile learning system in augmented reality context", *International Journal of Distributed Sensor Networks*, Vol. 2013 No. 1, pp. 1-7.

Chen, Y.T., Yang, C.L., Chang, Y.K. and Chu, C.P. (2009), "A RSSI-based algorithm for indoor localization using ZigBee in wireless sensor network", *Proceedings of the 15th International Conference on Distributed Multimedia Systems (DMS 2009), San Francisco*, pp. 70-75.

Di Serio, A., Ibáñez, M.B. and Kloos, C.D. (2013), "Impact of an augmented reality system on students' motivation for a visual art course", *Computers & Education*, Vol. 68 No. 10, pp. 586-596.

Duffy, T.M. and Jonassen, D.H. (1992), "Constructivism: new implications for instructional technology", *Constructivism and the Technology of Instruction: A Conversation*, Lawrence Erlbaum, Hillsdale, NJ, pp. 1-16.

Dunleavy, M., Dede, C. and Mitchell, R. (2008), "Affordances and limitations of immersive participatory augmented reality simulations for teaching and learning", *Journal of Science Education and Technology*, Vol. 18 No. 1, pp. 7-22.

Feng, Z., Duh, H.B.L. and Billinghurst, M. (2008), "Trends in augmented reality tracking I interaction and display: a review of ten years of ISMAR", paper presented at the 7th IEEE/ ACM International Symposium on Mixed and Augmented Reality (ISMAR), Cambridge, 15-18 September.

Fitzmaurice, G.W. (1993), "Situated information spaces: spatially aware palmtop computers", *Communications of the ACM*, Vol. 36 No. 7, pp. 38-49.

Gouveia, L.B. and Gouveia, F. (2002), "Evaluative ethnography and systems design: can it also be used to assess presence?", *The 5th Annual International Workshop on Presence*, Porto, 9-11 October.

Huang, T.C. (2014), "Antistray, learning smart: creating indoor positioning learning environment for augmenting self-regulated learning", *International Journal of Distributed Sensor Networks*, Vol. 2014 No. 1, p. 12, Article ID 427675.

Huang, T.C. (2015), "What Library 2.0 has taught libraries in Taiwan about e-learning", *The Electronic Library*, Vol. 33 No. 6.

Huang, T.C. and Chen, C.C. (2013), "Animating civic education: developing a knowledge navigation system using blogging and topic map technology", *Educational Technology & Society*, Vol. 16 No. 1, pp. 79-92.

Huang, Y.M. and Chiu, P.S. (2015), "The effectiveness of a meaningful learning-based evaluation model for context-aware mobile learning", *British Journal of Educational Technology*, Vol. 46 No. 2, pp. 437-447.

Huang, Y.M., Huang, S.H. and Wu, T.T. (2014), "Embedding diagnostic mechanisms in a digital game for learning mathematics", *Educational Technology Research and Development*, Vol. 62 No. 2, pp. 187-207.

Huang, Y.M. and Liang, T.H. (2015), "A technique for tracking the reading rate to identify the e-book reading behaviors and comprehension outcomes of elementary school students", *British Journal of Educational Technology*, Vol. 46 No. 4, pp. 864-876.

Klopfer, E. and Squire, K. (2008), "Environmental detectives: the development of an augmented reality platform for environmental simulations", *Educational Technology Research and Development*, Vol. 56 No. 2, pp. 203-228.

Knowles, M.S. (1975), *Self-Directed Learning: A Guide for Learners and Teachers*, Association Press, New York, NY.

Liang, T.H. and Huang, Y.M. (2014), "An investigation of reading rate patterns and retrieval outcomes of elementary school students with e-books", *Educational Technology & Society*, Vol. 17 No. 1, pp. 218-230.

Liu, W., Cheok, A.D., Mei-Ling, C.L. and Theng, Y.L. (2007), "Mixed reality classroom: learning from entertainment", *Proceedings of the 2nd International Conference on Digital Interactive Media in Entertainment and Arts, Perth, 19-21 September*.

Martin, S., Diaz, G., Sancristobal, E., Gil, R., Castro, M. and Peire, J. (2011), "New technology trends in education: seven years of forecasts and convergence", *Computers & Education*, Vol. 57 No. 3, pp. 1893-1906.

Pintrich, P.R., Smith, D.A. and Mckeachie, W.J. (1989), *A Manual for the Use of the Motivated Strategies for Learning Questionnaire (MSLQ)*, National Center for Research to Improve Postsecondary Teaching and Learning, School of Education, The University of Michigan, Ann Arbor, MI.

Riaz, Z., Arslan, M., Kiani, A.K. and Azhar, S. (2014), "A BIM and wireless sensor based integrated solution for worker safety in confined spaces", *Automation in Construction*, Vol. 45 No. 1, pp. 96-106.

Ting, S.L., Kwok, S.K., Tsang, A.H. and Ho, G.T. (2011), "The study on using passive RFID tags for indoor positioning", *International Journal of Engineering Business Management*, Vol. 3 No. 1, pp. 9-15.

Wang, T.H. (2011), "Developing web-based assessment strategies for facilitating junior high school students to perform self-regulated learning in an e-learning environment", *Computers & Education*, Vol. 57 No. 2, pp. 1801-1812.

Wang, Y.C. (2014), "Using wikis to facilitate interaction and collaboration among EFL learners: a social constructivist approach to language teaching", *System*, Vol. 42 No. 1, pp. 383-390.

Woo, S., Jeong, S., Mok, E., Xia, L., Choi, C., Pyeon, M. and Heo, J. (2011), "Application of WiFi-based indoor positioning system for labor tracking at construction sites: a case study in Guangzhou MTR", *Automation in Construction*, Vol. 20 No. 1, pp. 3-13.

You, J.W. and Kang, M. (2014), "The role of academic emotions in the relationship between perceived academic control and self-regulated learning in online learning", *Computers & Education*, Vol. 77 No. 1, pp. 125-133.

Zimmerman, B.J., Bonner, S. and Kovach, R. (1996), *Developing Self-regulated Learners: Beyond Achievement to Self-efficacy*, American Psychological Association, WA, DC.

Further reading

Chen, C.C. (2005), "Using data mining techniques to discover personalized book recommendation for library", *Journal of Educational Media & Library Sciences*, Vol. 43 No. 1, pp. 87-107.

Guenther, K. (2000), "Applying data mining principles to library data collection", *Computers in Libraries*, Vol. 20 No. 4, pp. 60-63.

Hoivik, J. (2013), "Global village mobile access to library resources", *Library Hi Tech*, Vol. 31 No. 3, pp. 467-477.

Johnson, L.F., Levine, A., Smith, R.S. and Haywood, K. (2010), "Key emerging technologies for elementary and secondary education", *Education Digest*, Vol. 76 No. 1, pp. 36-40.

Rekimoto, J. (1995), "The magnifying glass approach to augmented reality systems", *Proceedings of ICAT '95, Makuhari Meese*.

Rekimoto, J. and Nagao, K. (1995), "The world through the computer: computer augmented interaction with real world environments", *Proceedings of the 8th Annual ACM Symposium on User Interface and Software Technology, ACM, Pittsburgh, PA*, pp. 29-36.

Woo, Y. and Reeves, T.C. (2007), "Meaningful interaction in web-based learning: a social constructivist interpretation", *The Internet and Higher Education*, Vol. 10 No. 1, pp. 15-25.

Corresponding author

Tien-Chi Huang can be contacted at: tchuang@nutc.edu.tw