Intelligent Virtual Reality Tutoring System Supporting Open Educational Resource Access

Jae-wook Ahn[1](✉), Ravi Tejwani[1], Sharad Sundararajan[1], Aldis Sipolins[1], Sean O'Hara[1], Anand Paul[1], Ravi Kokku[1], Jan Kjallstrom[2], Nam Hai Dang[2], and Yazhou Huang[2]

[1] IBM T.J. Watson Research Center, Yorktown Heights, USA
{jaewook.ahn,rtejwan,sharads,asipoli,sean.ohara,anand.paul,rkokku}@us.ibm.com

[2] EON Reality, Inc., Irvine, USA
{jan,namhai,david.huang}@eonreality.com

Abstract. Virtual Reality is gathering increasing popularity for Intelligent Tutoring Systems. We introduce an approach that improves the baseline VR experience for ITS by enabling access to open educational resources and more intelligent navigation with the support of multiple artificial intelligence algorithms. A preliminary user study result not only reveals the potential of the proposed method, but also helps to identify the clues to improve the current design.

Keywords: Virtual reality · Intelligent Tutoring System
Open educational resources · Anatomic structure education

1 Introduction

There are a growing number of research publications in the recent years on using Virtual Reality for Education [8,9]. Virtual reality (VR) refers to technology that presents a three-dimensional environment via a head-mounted display. The display presents a slightly different image to each eye, creating an effect called binocular disparity that matches how we perceive the real world. The result is a convincing feeling of immersion, also called presence, that makes virtual environments feel real. By contrast, a virtual environment displayed on a conventional display is perceived as a flat image because it lacks binocular disparity.

For Intelligent Tutoring Systems (ITS), VR provides students with immersive experience, so that they can focus more on learning goals and gain knowledge that is hard to be learned from traditional training or from simple 2D visualizations. Among the various possibilities that VR ITS could provide, anatomic structure education has been one of the popular domains, e.g., [11]. It is due to the fact that the domain requires multi-dimensional representation of the objects (i.e., anatomic organs) with the ability to dissect those objects to better learn

R. Nkambou et al. (Eds.): ITS 2018, LNCS 10858, pp. 280–286, 2018.
https://doi.org/10.1007/978-3-319-91464-0_28

about them [5]. A large amount of the information it should deliver to the students also fits well with the immersive nature of the approach. However, we also feel that simple utilization of the 3D VR technology is insufficient to efficiently educate the required knowledge, considering the amount and the diversity of the learning materials.

In this paper, we introduce an approach to promote the use of VR in biology education, by linking the VR technology with various artificial intelligence and cognitive technologies such as exploratory search [7], recommendation, and adaptive navigation to open educational resources (OER) [3]. Several related approaches have been introduced for adaptive learning and hypermedia. For example, Chittaro and Ranon's approach [4] is very similar to ours. They discuss the adaptivity in the context of 3D Web sites and with respect to Web-based hypermedia, disassembling a particular object based on the ontology and providing educational resources to the learner. However, it is not an immersive VR representation as introduced in this paper. Brusilovsky [2] describe *adaptive navigation support* technologies that support user navigation in hyperspace, by adapting to the goals, preferences, and knowledge of the individual user. Kaufmann et al. [6] describe a 3D geometry construction tool specifically for mathematics and geometry education, based on mobile collaborative Augmented Reality. It promotes and supports dynamic exploratory behavior.

Inspired by these previous endeavors, we propose a novel VR Intelligent Tutoring System that supports direct manipulation and exploratory navigation of anatomic sub-structures and accessing open educational resources with the help of various artificial intelligence techniques. The adoption of those technologies on top of the VR interaction layer is critical in order to provide a better learning experience through more powerful search and navigation towards rich resources. We also provide a preliminary use case and user feedback results.

2 System Design and Implementation

We have designed a prototype system following the flow in Fig. 1. A learner interacts with a 3D frog model in a VR space. The model is comprised of hierarchical parts of a frog, which are viewed and manipulable from all directions and selected by a leaner using a pointer. An avatar provides verbal descriptions using Text-to-Speech (TTS) about a selected part so that the learner can learn about the characteristics of the part. A video content about the part is displayed on a virtual screen as well.

In addition to providing prescribed instructions about the frog organs, the system allows users to search for open educational resources and get recommendations from the system. It is known that users tend to provide too short queries (2 or 3 words) and not good at expressing their information needs with higher quality queries. It may be even more challenging to receive effective user queries in a VR environment where users' expressive capacity is limited than conventional web environment. Therefore, a mechanism to increase the search power of original queries is required by expanding them [12]. We employed an amphibian

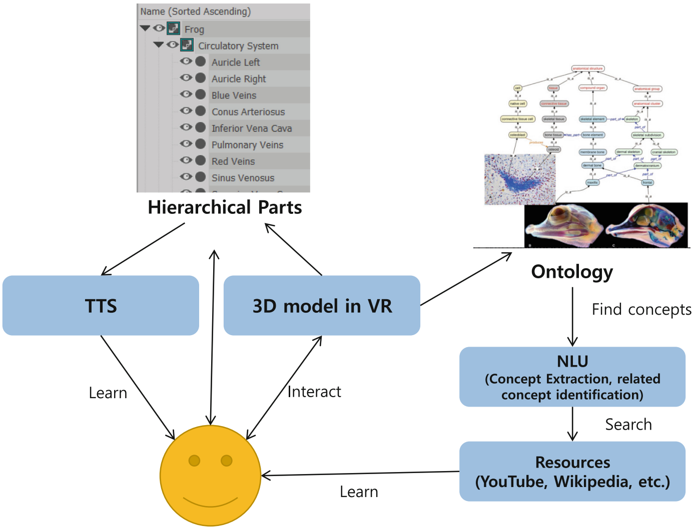

Fig. 1. VR ITS system flow. A learner interacts with a 3D model in VR and learns about a frog part through Text-To-Speech. She requests for related open resources about the part or recommendation for other related parts. The task is done by looking up the ontology, extracting concepts, and running search against online databases.

ontology (Amphibian Gross Anatomy Ontology (https://bioportal.bioontology.org/ontologies/AAO) [10]) and IBM Watson Natural Language Understanding (NLU) service [1]. Using the ontology, additional cues instead of a simple part name can be achieved. The ontology we used provides definitions of a specific amphibian part and information about the hierarchical relationships of it. The NLU module we used can extract concepts, keywords, and entities from any given texts, so we could select better query terms from the ontology information by avoiding noises. The expanded and refined queries are run against internal or third-party search engines and retrieves related resources. At the same time, related organs or parts can be recommended using the same information used for the search.

Figure 2 shows a screenshot of the prototype. The digital environment and interactions were created in the Unity3D (https://unity3d.com) game engine and rendered on a high-end desktop computer with a GTX 1080 graphics card. Users wore an HTC Vive (https://www.vive.com/us) headset to view the environment, which enables full rotation and position tracking in a room-scale (15'x15') space. Users interacted with objects by using wireless controllers included with the HTC Vive. The VR experience had users examine the skeletal and biological structure of a frog. A virtual avatar (Fig. 2(a)) guided the user through the experience by delivering verbal instruction via a cognitive Text-To-Speech service. Responses were pre-scripted and triggered by user interaction. For example, when the user is prompted to "look at the [frog's] right eye", the next verbal guidance is delivered

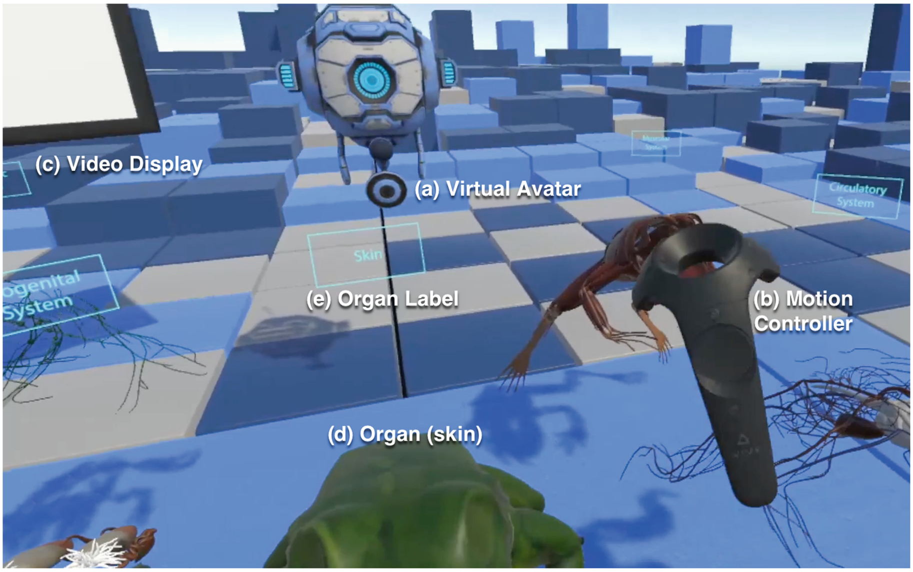

Fig. 2. VR ITS space screenshot. An anatomic structures of a frog is displayed in a 3D VR space. A learner explores the space, selects a part using a pointer, and learns about it. A Virtual Avatar plays a role of a tutor by providing verbal instructions or explanations.

only when the user rotates their headset in the direction of the relevant 3D model. Another interaction prompts the user to "select the skull" and proceeds only once the user has touched the frog skull with the motion controller (b). A virtual screen (c) floating in front of the user displayed supplemental video content to enrich the experience. Users could view a whole frog and then separate it into labeled (e) sub-structures (d). Users could also view a semi-transparent 'X-ray' version of the frog that made visible its biological substructures.

3 Prototype System User Study

We defined two research questions and conducted a preliminary user study about the prototype introduced in the previous section:

1. Is it easy to use the interactive elements (visual, voice, and the video recording) of the prototype while exploring the VR space?
2. Is it helpful to have access to adaptive navigation features such as OER resource search and related part recommendation?

For the study, twenty researchers were recruited within our institution. All the participants are experts in education technology research and development. In the first part of the user study, we presented a video recording showing the interaction use case of the prototype to the participants. The actual VR experience could not be provided due to the limited resources and the participants' locations but the user study was to test the visual aspects of the prototype and the lack of virtuality and the interactivity does not bias the results. It also ensures all participants having exactly the same experience to form their evaluations. In the second part, we asked each participant to try 3 queries against our frog part search facility that makes use of the AI technology-based query expansion and searching external resources. After the two trials, the participants were asked to answer a survey about the features of the prototype using a 5-point Likert Scale.

About the VR experience, the first group of the questionnaires asked about the effectiveness of the visual elements of the prototype: 3D frog parts, frog part labels, and the overall layout of the parts. The second group is about the audio related features such as voice instructions and explanations. The last group is about the OER access: related materials and navigation. Table 1 summarizes the results. Overall, the participants expressed positive experiences about the system (average score = 4.0 out of 5.0). They were satisfied with the quality of the TTS features (4.13 and 4.07) and gave high scores to the possibility of the OER resource search and the navigation feature (4.07 and 4.20). However, the visual elements needs improvements. Especially the layout of the frog parts recorded the lowest (2.93). This may be because the parts were scattered around the space for exploration but cluttered the space at the same time. A better approach needs to be developed that can adaptively locate, reduce clutter, and decide more efficient layout of the objects in the virtual space.

Table 1. User feedback on VR interaction

Visual				TTS		Resources		
Parts	Labels	Layout	Video	Instruction	Explanation	Related materials	Navigation	Overall
4.13	3.93	2.93	4.07	4.13	4.07	4.07	4.20	4.00

The second part that asked about the effectiveness of the query expansion and searching is less satisfactory (Table 2). We asked the participants to rate the quality of the expanded query and the search results. The scores are slightly above the neutral which reflects dissatisfaction from some of the participants. After examining the search log, we found that only 7 out of 35 queries entered by the participants were expanded using the ontology and the NLU. Several queries (part names) did not match with the ontology headings due to the difference of the languages and that lead to the failure to apply the NLU service and eventually may have affected the final search results.

Table 2. User feedback on query expansion and searching

Query expansion quality	Search quality using the expanded query
3.60	3.31

4 Conclusions

In this paper, we introduce a Virtual Reality based Intelligent Tutoring System that teaches amphibian anatomy. In addition to the conventional VR experience, we attempt to empower the VR with an ability to navigate and access open educational resources with the help of artificial intelligence technologies. A prototype was designed and implemented, and a preliminary user study was conducted to answer initial research questions. The participants of the user study provided important information on improving the current implementation as well as supporting the potential of our approach. We plan to enhance the visual layout of the learning objects within the VR space by developing adaptive layout methods within the VR space. We also plan to address the issues of our educational resource access algorithm discovered during the user study.

References

1. Watson Natural Language Understanding (2018). https://www.ibm.com/watson/services/natural-language-understanding/
2. Brusilovsky, P.: Adaptive navigation support. In: Brusilovsky, P., Kobsa, A., Nejdl, W. (eds.) The Adaptive Web. LNCS, vol. 4321, pp. 263–290. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-72079-9_8
3. Brusilovsky, P.: Adaptive navigation support for open corpus hypermedia systems. In: Nejdl, W., Kay, J., Pu, P., Herder, E. (eds.) AH 2008. LNCS, vol. 5149, pp. 6–8. Springer, Heidelberg (2008). https://doi.org/10.1007/978-3-540-70987-9_2
4. Chittaro, L., Ranon, R.: Adaptive 3D web sites. In: Brusilovsky, P., Kobsa, A., Nejdl, W. (eds.) The Adaptive Web. LNCS, vol. 4321, pp. 433–462. Springer, Heidelberg (2007). https://doi.org/10.1007/978-3-540-72079-9_14
5. Jang, S., Vitale, J.M., Jyung, R.W., Black, J.B.: Direct manipulation is better than passive viewing for learning anatomy in a three-dimensional virtual reality environment. Comput. Educ. **106**, 150–165 (2017)
6. Kaufmann, H., Schmalstieg, D., Wagner, M.: Construct3D: a virtual reality application for mathematics and geometry education. Educ. Inf. Technol. **5**(4), 263–276 (2000)
7. Marchionini, G.: Exploratory search: from finding to understanding. Commun. ACM **49**(4), 41–46 (2006)
8. Marks, S., White, D., Singh, M.: Getting up your nose: avirtual reality education tool for nasal cavity anatomy. In: SIGGRAPH Asia 2017 Symposium on Education, SA 2017, pp. 1:1–1:7. ACM, New York (2017)
9. Merchant, Z., Goetz, E.T., Cifuentes, L., Keeney-Kennicutt, W., Davis, T.J.: Effectiveness of virtual reality-based instruction on students' learning outcomes in K-12 and higher education: a meta-analysis. Comput. Educ. **70**, 29–40 (2014)

10. Musen, M.A., Noy, N.F., Shah, N.H., Whetzel, P.L., Chute, C.G., Story, M.-A., Smith, B., NCBO Team: The national center for biomedical ontology. J. Am. Med. Inf. Assoc. **19**(2), 190–195 (2011)
11. Seo, J.H., Smith, B.M., Cook, M., Malone, E., Pine, M., Leal, S., Bai, Z., Suh, J.: Anatomy builder VR: applying a constructive learning method in the virtual reality canine skeletal system. In: Andre, T. (ed.) AHFE 2017. AISC, vol. 596, pp. 245–252. Springer, Cham (2018). https://doi.org/10.1007/978-3-319-60018-5_24
12. Xu, J., Croft, W.B.: Query expansion using local and global document analysis. In: Proceedings of the 19th Annual International ACM SIGIR Conference on Research and Development in Information Retrieval, SIGIR 1996, pp. 4–11. ACM, New York (1996)