Foreign language learning in immersive virtual environments

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ABSTRACT

Virtual reality has long been used for training simulations in fields from medicine to welding to vehicular operation, but simulations involving more complex cognitive skills present new design challenges. Foreign language learning, for example, is increasingly vital in the global economy, but computer-assisted education is still in its early stages. Immersive virtual reality is a promising avenue for language learning as a way of dynamically creating believable scenes for conversational training and role-play simulation. Visual immersion alone, however, only provides a starting point. We suggest that the addition of social interactions and motivated engagement through narrative gameplay can lead to truly effective language learning in virtual environments. In this paper, we describe the development of a novel application for teaching Mandarin using CAVE-like VR, physical props, human actors and intelligent virtual agents, all within a semester-long multiplayer mystery game. Students travel (virtually) to China on a class field trip, which soon becomes complicated with intrigue and mystery surrounding the lost manuscript of an early Chinese literary classic. Virtual reality environments such as the Forbidden City and a Beijing teahouse provide the setting for learning language, cultural traditions, and social customs, as well as the discovery of clues through conversation in Mandarin with characters in the game.

Keywords: Serious Games, Language Learning, Virtual Environments, Alternate Reality Games

1. INTRODUCTION

1.1 Computer-Based Learning Systems

Computer aided pedagogical systems and intelligent pedagogical agents have been widely used for tutoring and training purposes, ranging from math[1] and physics tutoring[2] to language and social skill training[3, 4], and from life style suggestions[5] to PTSD[6] and Autism interventions[7].

Compared to traditional classroom training and human tutors, computer-based systems have several advantages. First, they can be used at the user's convenient time and locations, and therefore increase the overall time the students can spend on the subject. Secondly, the system can be adaptive to each individual's need and progress, and therefore create a personalized learning environment. Thirdly, a computer-based system can foster learning and encourage interactions from users who are not comfortable interacting with other humans. Fourthly, computer-based systems can be copied and therefore be deployed at multiple locations at the same time. Fifthly, a computer-based system can be used to record and keep track of the students' work, allowing for a cleaner and more organized re-presentation of the student's work (which helps both the student and instructor in their respective task), the taking care of various necessary but relatively unimportant bookkeeping tasks, and the collecting of user data that can be used to research the effectiveness of the program. Sixth, and finally, computer-based learning systems can often be a cheaper choice than human instructors or tutors.

Computer-based language learning presents both additional potential benefits and specific challenges. Language is inextricably linked to both the context of immediate use and the wider context of culture. Simulating real-world scenarios offers a way to acquire and practice language in context, while using game design to structure the learning

The Engineering Reality of Virtual Reality 2012, edited by Ian E. McDowall, Margaret Dolinsky,
Proc. of SPIE-IS&T Electronic Imaging, SPIE Vol. 8289, 828902 · © 2012 SPIE-IS&T
CCC code: 0277-786X/12/$18 · doi: 10.1117/12.909835

experience provides an immediate motivating factor and focus. As in real life, successful comprehension and language use is a way for the student to accomplish something they are personally invested in. Believable and compelling narrative, either in the simple form of basic interactions or a complete fictional story, is necessary both for a realistic simulation and to foster a deep level of engagement. The accompanying technical challenges include the creation of compelling immersive visual simulations, flexible and dynamic interactive narrative structures, and sufficiently sophisticated synthetic characters who can communicate with students in a believable manner.

While most computer-based language learning systems are aimed at a standard personal computing environment, the effective use of language training has also been demonstrated in fully immersive virtual environments such as the Tactical Language Training System.[8] O'Brien, Levy, and Orich describe a CAVE-based language learning environment targeted at more general L2 applications, in which students explore a virtual model of Vienna in search of the mayor's missing daughter.[9] In the work presented here we begin by first considering the importance of interactive narrative and game design in the creation of an immersive learning experience.

1.2 Presence

Giving the viewer/user an experience of being present in the fictional world is a design goal across media forms. In studies of films, the diegetic effect is defined as the "experience of the fictional world as the environment" or "the illusion of being present in the fictional world"[10]. The diegetic effect is believed to be essential for triggering the user's affective response[11]. Similarly, in text based narratives, e.g., books, the effect of "transportation" to the fictional world is often a design goal. Green has identified the experience of "presence" as a mechanism of narrative impact.[12] While researchers on video games usually do not specifically emphasize this phenomenon, in the more general virtual reality society the user's experience of presence is often the fundamental goal, as the experience of presence is important for both providing entertainment[13] and ensuring the efficiency of virtual training and the transferring of knowledge and skills to the real world thereafter.[14]

Virtual environments often seek to create two types of presence for the user. The first type of presence is physical/spatial/environmental presence, which is often desired in training scenarios where physical realism is important, such as simulations for training air force pilots, for phobia treating[15] and for post-traumatic stress therapy. The other type of presence is social presence. Heeter defines it as "the extent to which other beings in the world appear to exist and react to the user".[16] Biocca et al. describe social presence as "perceived access to another intelligence (not necessarily a real human)"'.[17] Our project aims to generate a combination of social presence and physical presence in an augmented virtual environment.

Many factors contribute to the experience of presence. In order for the user to feel presence in a virtual environment, the content of the virtual environment needs to be meaningful.[18] The user should be able to form a mental model of the virtual world.[19] The user should know his/her own possible actions and be able to anticipate the results of his/her actions as well as other characters/objects' actions/movements.[20] For virtual environments that contain narratives, the quality of the narrative also affects the user's sense of presence.[21]

In addition to these factors, which address the content of the virtual environment, the physical properties of the environment also play an important role in inducing the experience of presence. Most notable factors are the immersive quality of the simulation and the amount of interactivity allowed by the environment. In general, the more inclusive, extensive, surrounding and vivid the virtual environment is, the higher the experience of presence.[22] Interactivity and the sense of agency have also been shown to affect the experience of presence. The more natural and unconstrained the interaction is, the higher degree of presence will be experienced by the user.

Presence is also closely related to the classical literary concept of "willing suspension of disbelief."[23] This action/mental process enables the user to feel that the virtual environment is real, and therefore is an important factor for the user to experience presence.[24] Evidence show that this process probably happens unconsciously.[25] How much the user can tolerate the unrealism in the virtual environment is related to the utility of the interaction.[26] For example, if fully immersing into the interaction is enjoyable, the user would be more willing to believe the virtual environment is real and ignore imperfections in the simulation.

In this project, we created the experience of presence through immersing the user with a big interactive 3D display of the virtual world, in combination with physical objects in the real world and human actors the user can interact with.

2. THE LOST MANUSCRIPT

2.1 Design

While educational games are often used as discrete elements within a class, we used a novel method developed by the second author which uses play and game structures as the fundamental pedagogical strategy. Rather than using a game as one element within the framework of a class, the entire course is transformed into a game.[27] All course elements are recontextualized as game elements, such that every part of the class experience is framed within the game and within its story. In game design terms, the whole course stays within the Magic Circle. This approach can also be seen as a way of maximizing a sense of presence using interactive agency, social presence, dramatic suspension of disbelief, and the removal of separation between the real and virtual world. One crucial part of this process is maintaining a sense of internal coherence with a game world appropriate to the course at hand. For example, in a class on game design, grades become "experience points" and the whole learning process of mastering progressively more challenging material becomes a process of "leveling up." In our game for language learning, these pedagogical elements take on completely different forms to fit within the narrative framework. This model of game design is similar to the Alternate Reality Game, or ARG, in which the line between game and reality becomes blurred. Drawing on previous successes in designing educational ARG's,[28] we developed a beginning course in Mandarin structured as a game entitled "The Lost Manuscript." In this semester-long alternate reality game students travel to China (virtually) in search of a priceless first edition copy of the Chinese classic "Outlaws of the Marsh," encountering mystery and intrigue along the way.

The game involves puzzles and problem solving, but more importantly immersion, spatial reasoning, and social interaction. The implementation of the game relies on two key elements: an immersive space to create the sense of presence in the game's locations, and rich, believable interactions with the non-player characters. Our proposed approach to the element of immersion is a mixed-reality environment, combining a semi-panoramic rear-screen stereoscopic projection with physical props. For example, an episode where students visit a teahouse in Beijing would feature physical tables and real tea, surrounded by VR projection of the overall environment.

2.2 Story Summary

The game begins as a normal college course in Mandarin Chinese, including a study trip to Beijing. Throughout the semester, students meet a cast of characters who introduce different language lessons and aspects of Chinese cultural. Each of these characters is independently hunting for the lost manuscript, and tries to get the students to help in their search. Students have to utilize spoken and written language comprehension and usage skills to get clues through conversation, decipher codes and solve puzzles, and navigate everyday activities and interactions. The class / game is designed for beginning students, so it makes use of introductory vocabulary and conversation patterns. The game structure creates a situation where at each step something is at stake, either in the search for the valuable manuscript or in the developing relationships with the different characters. This creates a heightened level of investment in even basic things like asking for directions or ordering a cup of tea. This sense of urgency increases over the course of the semester as the plot unfolds and additional layers of intrigue are revealed. At five weeks into the class we also split the loyalties of the students among the different non-player characters, with each one telling students not to trust the others. While most of the game is designed as a cooperative group activity, this introduces an additional layer of competition between groups of students.

The game is structured as a series of weekly episodes, each one focused around a set of language skills, narrative development, and puzzles or challenges. In the first episode, the class begins like any average class in Mandarin. The teacher, Tang Laoshi, welcomes the class and tells students that they may have an opportunity to take a study trip to Beijing the following semester sponsored by an organization called The Heritage Library. She introduces some basic phrases such as greetings and identities. Strangely, she also teaches them the phrase "I am looking for a book," but doesn't fully explain why. In the second week's episode, Tang Laoshi delivers the surprising news that the Heritage Library will be sending the class to Beijing this semester, not next semester, so they will have to learn quickly. By the end of the first few weeks, students have learned the phrases they'll need to navigate the Beijing airport and find their guide, Dr. Chen. They've also encountered Tingting Lu, an importer who offers to help with anything they might need while in China; but who their teacher, Tang Laoshi, has warned them not to trust.

In Episode Four, the students travel to Beijing. After making their way through customs (in Chinese) they are supposed to meet Dr. Chen, who will take them to their hotel. However, Dr. Chen is not there. Instead they find a sign with "RENSSELAER STUDENT GROUP" written on it, crumpled up on the floor. Now they have to figure out how to call their hotel and ask for a van; they also meet an elderly woman named Mrs. Ling who asks for a ride to the hotel with them.

Over the next few episodes, students discover that Mrs. Ling is in fact a literature professor who also works for the Heritage Library, and is in China on behalf of the library searching for an incredibly rare first edition of *Outlaws of the Marsh* which is rumored to have just come to light. She also brings the class to a traditional teahouse, where they learn a tea ceremony and play a language game with the waiter, Pei, who they may or may not recognize as the customs official from the airport. Tingting Lu reappears, warning students not to trust Mrs. Ling. Dr. Chen is still missing. By Episode 7, Mrs. Ling is trying to get the students to help her find the book; Tingting Lu tells them that Ling and Tang Laoshi are both planning to cheat the Heritage Library and sell the book to a private collector; and Pei, who reveals himself to be a police inspector, asks for their help in locating Dr. Chen. Tang Laoshi finally receives a cryptic message from Dr. Chen, which turns out to be in Chinese, but in some kind of code. By breaking the code, students reveal a date, time, and a location in the Forbidden City – an old Imperial library. There they finally find Dr. Chen, who tells them that he believes there are clues hidden in the chamber that will lead to the current location of the book. The students search the library, piecing together the path to book's hiding place – but just as they've solved the puzzle, Inspector Pei appears and demands they come to police headquarters. There, he questions them in Chinese about everything they've done in Beijing, and in particular everything having to do with the book. This interrogation is the final exam for the class.

Figure 1: going through customs at the Beijing Airport

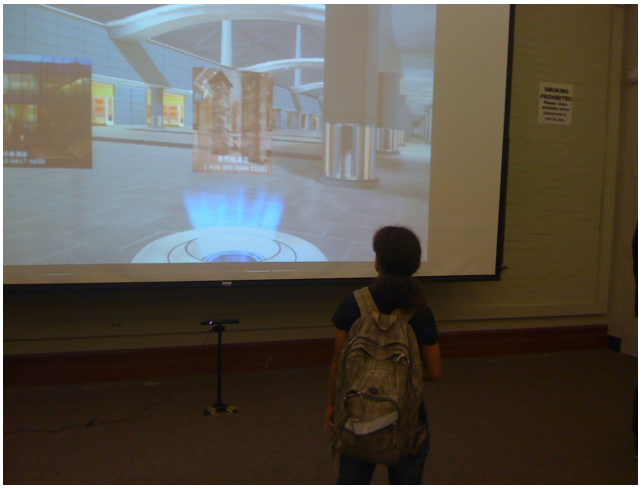

Figure 2: Kinect-enabled Beijing Airport module

2.3 Virtual Reality and Alternate-Reality Games

This experimental course was initially designed around a new VR facility currently scheduled to open in 2012. As an initial prototype, the course was first implemented as a low-tech Alternate-Reality Game (ARG) using a combination of human actors, physical props, and games using the Microsoft Kinect – what we termed a "dress rehearsal." The course took place over eight weeks in Fall 2011 with 12 students, all with little or no prior knowledge of Mandarin. Additional ARG elements included the use of websites and text messages to extend the game world; for example, most course materials were housed in a website for the fictional Heritage Library, while game characters sent text messages to students throughout the semester with clues and efforts to gain their loyalty. The course staffing included the primary instructor (who also played the role of language instructor Tang Laoshi), a cast of amateur actors who were native Mandarin speakers, and faculty and students behind the scenes (the "puppetmasters," in ARG terminology). The major game and narrative interactions took place in weekly episodes, augmented by preparation sessions with the course instructor that used more traditional language instruction techniques as well as online video resources to reinforce

pronunciation. After the first class students were divided into four groups by ability, so that each group had a stronger learner, a weaker learner, and one somewhere in between. The design of the challenges throughout the course emphasized collaborative learning and problem-solving, along with a competitive element between the teams as each team became allied with one of the competing NPC's.

While the majority of the course was implemented using physical spaces and live actors, we introduced digital virtual environments in four episodes: the Beijing Airport, the Teahouse, the Code-breaking episode, and the Forbidden City. These were presented as large monoscopic projections as a backdrop to the physical set, with different forms of interaction using the Kinect. In the Beijing Airport episode, for example, students encountered a "holographic" information kiosk, containing visitor information about hotels, restaurants, and attractions in Beijing. The interaction sequence is also a part of the challenge for this episode; their contact, Dr. Chen, is nowhere to be found, and they are stranded in the airport. By successfully navigating the information kiosk, students are able to find the phone number for their hotel; they can then dial the number on a physical phone in the classroom, talk to the "front desk" at the hotel in Mandarin, and ask for a van to pick them up at the airport.

2.4 Interaction Design with the Microsoft Kinect

The virtual environment sequences were created using the Unity3D[29] game engine, the OpenNI and NITE[30] libraries for gesture recognition and hand tracking, an open-source OpenNI-compliant sensor module for the Kinect, and the Zigfu[31] OpenNI bindings for Unity3D. This solution provided both rapid development ability and a professional level of visual quality expected in current commercial games. Each of the episodes utilizing a virtual environment had a different form of interaction. The Airport episode used hand gestures to move through menus and submenus, scroll through sets of images, and navigate a map. A later episode set in the Forbidden City used hand tracking to open cabinets and boxes, pick up hidden objects (photographs), and arrange them to unveil clues. We found that in each case, students were able to quickly understand the interface and use it to tackle the challenge. We also found that the cast of non-player-characters (all of a non-gamer generation) were able to understand and use the interface very easily. The primary usability difficulty we observed was in depth-based (Z-axis) motions, such as reaching into a cabinet to grab an object or using a "push" gesture to activate a GUI element in the airport kiosk. We expect that this can be improved through better calibration of the scaling between real world and game space depth, as well as through the use of stereoscopic display.

Figure 3. Screenshot of Beijing Airport interactive module.

2.5 Codebreaking

The Kinect was used in different ways throughout the game, but one episode presented particularly interesting challenges in interface and game design. For the third environment in our sequence, the goal was to design a puzzle game/activity

which tested the student's use of key vocabulary in context. As we had already generated two environments in realist physical spaces, we chose to situate the third in an abstract screen space.

Given the theme of 'codebreaking' to work with, we initially proposed a manipulatable interface or object which functioned as a progressively unlocking structure utilizing a puzzle mechanic akin to a cypher. We quickly encountered several design challenges. Transposition-style cyphers were far too simple with only five components to the answer. Substitution cyphers also proved to be non-ideal as their use is often tied to training process tangential to our learning goals.

The design we ultimately settled on was a somewhat simpler grid-based scrambled code. Five columns, each filled with three vocabulary words grouped by word type, stand horizontally in a line. The interactor can use a cursor guided by Kinect hand-tracking to perform three different actions. They may swap the positions of any two adjacent columns with a button press. They may also press any column, and drag it vertically, selecting one of the three words it contains. Lastly, they may check if their solution is correct by pressing a check button. Should their solution be incorrect, the puzzle's appearance is momentarily obscured with a pixelation effect and re-scrambled. This prevents the puzzle from being brute forced rapidly through trial and error. If the interactor gets the solution correct, by selecting the correct words and arranging the columns in grammatically correct order, the puzzle elements fade and the full sentence (the code being sought in the ARG narrative) is expanded and shown to the interactor.

In generating the aesthetic of the codebreaking puzzle, efficient production of assets was critical due the time constraints of the project. We created a layered series of animated particle effects to add an archetypal visual theme of something 'holographic'. Some real-time post processing was also added to emphasize the visual effect. The entire scene was lightweight, and ran at incredibly high frame rates. Aside from occasional calibration inconsistencies, the Kinect hand tracking worked reliably. We did however take the precaution each play session to encourage only one individual standing within the infrared camera's view, to ensure the Kinect did not get confused and track incorrectly.

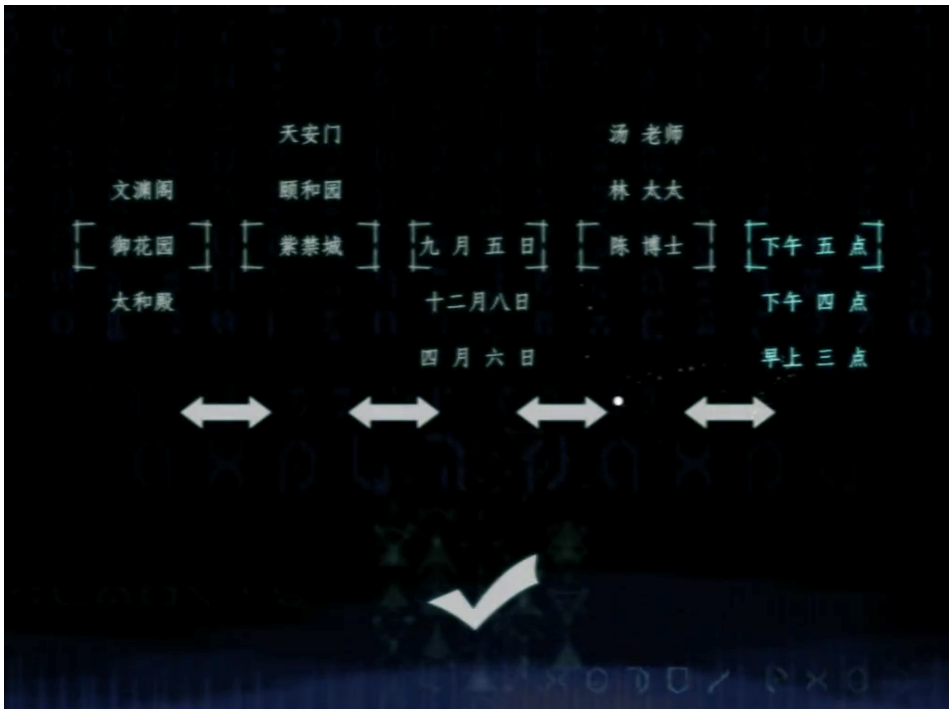

Figure 4: Codebreaking interactive module

3. RESULTS

The project is still in a preliminary stage, but we were able to make some initial observations to guide the creation of the fully immersive virtual environment in the project's next phase. The students were given a survey before the course to assess their background knowledge and expectations, and another survey after completion of the course to assess the value of the different course components. 11 out of 12 students responded. Overall, response to the narrative game structure was very positive. All felt the narrative was engaging, to varying degrees. Students described the immersive experience as "conducive to learning quickly, but … also often stressful," and also highlighted the value of interaction with native speakers and the way it forced them to test their confidence. When asked if the narrative improved learning, most (7 out of 11) agreed that it did: "the narrative was like being immersed in the language. Being forced to speak and understand Mandarin helped me remember it better and put it in context." Other responses pointed to the way that the narrative forced them to study, and provided "real-world experience." Some areas for improvement included the level of challenge and balancing collaborative and individual learning modes. Students were frequently able to complete the challenges in the narrative interactions in far less time than we expected. However, a number of students felt that it was "too easy to skate by without participating" in the interactive episodes, and that they wished there was more 1-on-1 interaction. When asked to rate the value of the other course elements, students gave particularly high ratings to the "prep sessions" with the course instructor, as well as to the online videos and other study materials. The lowest-rated element was the use of texting and social media with the fictional game characters; while some reported that texts "made the experience more realistic," most found them less useful and even an annoyance.

Overall, students were successful in the course and reported that it met or exceeded their expectations. The course instructor also reported an exceptionally high level of engagement and rapid acquisition of the material compared to other Mandarin courses at the same level. The students became involved enough in the narrative and immersed enough in the experience to be nervous going through "Beijing" customs; and interested enough to question characters about narrative points beyond the expected scenario. They tackled "assignments" such as code-breaking; mastering the tea ceremony; and searching a library within the Forbidden City with focus and intelligence; and solving puzzles within a few minutes that we'd expected would take the better part of an hour. Despite the challenges presented by the low-tech form of the immersive space, the narrative and gameplay elements drew the students in, as we've seen in video game research to the point where their learning ability was heightened by the presentation of a familiar entertainment that still required strong focus and an avid desire to learn.

In the next phase of the project, we will begin the transition from live-action alternate-reality gaming to immersive virtual environments. Our observations thus far, though only preliminary, suggest that our narrative game model can be effective in language learning. Questions in the next phase will focus on the effect of the transition from real to virtual environments and from real to virtual characters.

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