Investigating Intelligent Agents in a 3D Virtual World

Research-in-Progress

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Abstract

Web 3.0 involves "intelligent" web applications that utilize natural language processing, machine-based learning and reasoning, and intelligent techniques to analyze and understand user behavior. In this research, we empirically assess a specific form of Web 3.0 application in the form of intelligent agents that offer assistance to users in the virtual world. Using media naturalness theory, we hypothesize that the use of intelligent agents in the virtual world can enhance user experience by offering a more natural way of communication and assistance to users. We are interested to test if media naturalness theory holds in the context of intelligent agents that function as non-player characters in the virtual world. Through this research, we will not only assess the efficacy of a Web 3.0 application but also offer guidelines for creating intelligent agents in the virtual world.

Keywords: Web 3.0, intelligent agents, media naturalness theory, virtual world

Introduction

A virtual world is a computer-based simulated environment intended for its users to inhabit and interact via avatars (Jarvenpaa et al. 2007; Sutanto et al. 2011). It has become a popular platform used in a variety of contexts, including business, education, social sciences, technological sciences, and our society at large (Messinger et al. 2009). With increasing usage, virtual worlds have steadily shifted to the complex adaptive systems which rely heavily on the technology of agent-based simulation (Miller and Page 2007).

The Web environment has progressed from Web 1.0 and Web 2.0 to Web 3.0. Web 3.0 is based on "intelligent" web applications using natural language processing, machine-based learning and reasoning, and intelligent applications such as the use of intelligent agents (Baltzan, 2013). In virtual worlds, agents are usually implemented in the form of avatars, where they typically perform tasks like human beings in the real world. Two key properties of these agents are autonomy and interactivity. Agents should function autonomously and make decisions proactively in response to events happening in the virtual world around them. Also, their interaction with users should be as natural as possible. In the field of computer science, numerous works have been carried out to incorporate various agents in virtual worlds using the convergence of a diverse range of technologies, including computer graphics, 3D animation, cognitive science, natural language processing, decision making, dialog management, speech and gesture generation, and human-computer interaction. The goal is to have virtual agents that not only are intelligent but also interact with users in a natural way to enhance overall user experience in the virtual world. To the best of our knowledge, we have not come across any systematic empirical study that has evaluated whether the use of intelligent agents in the virtual world can help to improve user experience.

The rest of the paper is structured as follows. In the next section, we will provide a brief review of related work. Following that, we discuss the theoretical foundation and hypotheses related to how and why intelligent agents are expected to enhance user experience in the virtual worlds. We then present the research methodology and provide expected contributions of this research.

Background and Literature Review

Despite the number of significant work in building agents in virtual worlds, very little work has been carried out in investigating agent-based virtual worlds. Chaturvedi et al. (2011) have examined the design, development, validation, and use of virtual worlds, especially those using agent-based simulation as the underlying technology. They derive a set of design principles based on deep versus emergent structures while developing extended design principles to facilitate their integration. Nowak and Biocca (2003) have conducted an experiment to examine the influence of agents on presence, copresence, and social presence in a virtual environment. The result show that people respond socially to both humans and agents. Barfield and Hendrix (1995) found that agents shaking continuously or appearing to move between large discrete positions will likewise diminish a participant's sense of presence.

In the ancient City of Uruk 3000 B. C. within Second Life, virtual agent based Non-Player Characters (NPCs) could be the knowledge carriers as well as an important element in establishing the connection between the environment, objects and knowledge (Bogdanovych et al. 2009). In social simulations, studies have shown that synthetic characters in the form of NPCs have provided an engaging and believable experience for the trainees in their training on leadership and negotiation tactics (Swartout 2006; Riedl and Stern 2006) as well as in creating more dramatically interesting game situations (Prendinger and Ishizuka 2001). Besides social simulations, virtual patients for the assessment and training of novice clinicians have been evaluated as well. The evaluation shows that they can provide valid, reliable and applicable representations of live patients (Triola et al. 2006). Further evaluation also indicates that the interactions between novice clinicians and virtual patients resulted in a compatible dialectic in terms of rapport, discussion of the traumatic event, and the experience of intrusive recollections (Kenny et al. 2008).

Table 1. Summary of Applications of Agents in Virtual Worlds		
Reference	Application	Findings on Agents
Bogdanovych et al. (2009)	Uruk 3000 B. C. in Second Life	Function as knowledge carriers and an important element in establishing the connection between the environment, objects and knowledge
Swartout (2006)	Military training and Negotiation tactics	Provide an engaging interactive experience
Riedl and Stern (2006)	Leadership training	Provide an engaging and believable experience
Prendinger and Ishizuka (2001)	Games	Create dramatically interesting game situations
Triola et al. (2006)	Virtual patient	Provide valid, reliable and applicable representations
Kenney et al. (2008)	Virtual patient	Result in a compatible dialectic in terms of rapport, discussion of the traumatic event, and the experience of intrusive recollections

Theoretical Foundation and Hypotheses

Theoretical Foundation

Media Naturalness Theory

From an evolutionary standpoint, synchronous face-to-face (FTF) communication has been the primary mode of communication in the evolutionary history of human beings, which means that humans are optimized for FTF interaction (Kock 2004). Media Naturalness Theory (MNT), developed by Kock (2004), has been commonly used to understand human behavior toward technology in various contexts such as education, knowledge transfer, and communication in the virtual environments. Kock pointed out that in media naturalness theory, the naturalness of a communication medium is defined as the degree of similarity of the medium with the face-to-face medium. There are five key elements in natural communication (Kock 2004, 2005):
(1) Co-location, where individuals could engage in a communication interaction to share the same context.
(2) Synchronicity, where communication stimuli could be exchanged quickly during an interaction.
(3) Ability to convey and observe facial expressions.
(4) Ability to convey and observe body language.
(5) Ability to convey and listen to speech.

These five key elements in MNT could help to explain the value of intelligent NPCs in virtual worlds. Appearing as avatars inhabiting in virtual worlds, intelligent NPCs not only look the same as users, but also behave like humans (i.e., in verbal and non-verbal behaviors such as facial expression and body language). Specifically, verbal behaviors of intelligent NPCs involve understanding user's intention (via natural language understanding) and generating speech in real time (i.e., speech generation). These features of intelligent NPCs match the key elements in MNT; therefore, intelligent NPCs offer a more natural way in communication than those NPCs without these intelligent features.

According to MNT, an increase in medium communication naturalness can also decrease human cognitive effort and communication ambiguity, and increase physiological arousal (Kock 2004, 2005). Hence, intelligent NPCs that offer these features can enhance user experience in the virtual world.

Hypothesis Development

Drawing on MNT, we hypothesize that incorporating intelligent NPCs into a virtual world can enhance user experience by increasing interactivity, social presence, and user enjoyment.

Interactivity

Intelligent agents can be used to enhance interactivity in the virtual world environment. There are three dimensions in interactivity: active control, two-way communication, and synchronicity (Liu 2003). In the context of virtual worlds, the following two aspects are relevant: control and reciprocal communication. Control helps to ensure a reciprocal exchange that satisfies the needs of all communicating parties, while reciprocal communication provides an effective channel for exerting control (Liu 2003). By employing intelligent NPCs with natural language understanding capabilities, two-way communication and flow of information are facilitated. Users also perceive a high degree of control in their communications with intelligent NPCs. Based on MNT, an increase in medium communication naturalness by intelligent agents can facilitate reciprocal communication and control, thus increasing the overall level of interactivity. Hence, the following hypothesis is proposed:

H1: A virtual world with intelligent NPCs will facilitate a higher degree of interactivity than a virtual world without intelligent NPCs.

Social Presence

Intelligent agents can be used to enhance social presence in the virtual world environment. Social-presence, as a subcomponent of presence, is composed of social richness, social realism and co-presence (Lombard and Ditton 1997). Incorporating intelligent NPCs into a virtual world can enhance social-presence in the following aspects:
(1) Augment social richness by extending the environment to become more personal and intimate. Intelligent NPCs that are friendly and able to provide personal services to users will offer a more socially enriched environment.
(2) Increase social realism by simulating real-world people and events. Intelligent NPCs could simulate real-life activities such as attending events with users.
(3) Enable users' feeling of co-presence that they are together with other agents (Thomas and Brown 2009).

Face-to-face communication is regarded to have the highest social presence since verbal and nonverbal cues can be most effectively communicated in a face-to-face setting (Carlson and Davis 1998). In a virtual world environment, intelligent NPCs can communicate to users through verbal and non-verbal cues including facial expression and body gestures. According to MNT, high degree of synchronicity, body language, facial expression and speech are the key properties for a communication medium to be as natural as face-to-face communication. Hence, a virtual world environment that incorporates intelligent NPCs in the form of avatars is hypothesized to increase social presence in the environment.

H2: A virtual world with intelligent NPCs will facilitate a higher social presence than a virtual world without intelligent NPCs.

User Enjoyment

Intelligent agents can be used to enhance user enjoyment in the virtual world environment. Based on MNT, medium communication naturalness, which can be facilitated by the use of intelligent agents, can decrease human cognitive effort and increase users' physiological arousal, both of which can increase user enjoyment (Kock 2005). Hence, the use of intelligent agents in the virtual world can increase naturalness and engagement in communication interactions, thus increasing user enjoyment in the virtual experience. Therefore, the following hypothesis is proposed:

H3: A virtual world with intelligent NPCs will facilitate a higher level of user enjoyment in the user experience than a virtual world without intelligent NPCs.

Research Methodology

A between-subject experiment will be used to test the hypotheses. We developed two virtual world environments with two different types of virtual agents in the form of NPCs inhabiting the environment. These NPCs take the form of human-like avatars.

The first environment (E1) is the control condition where the NPCs are only able to show and display static messages to users and they do not possess the capability to interact with the users. The second environment (E2) is the treatment condition where the same environment as E1 (control) is also inhabited by intelligent autonomous NPCs that communicate with and offer help to users. These NPCs utilize artificial intelligence and neural network techniques to function autonomously using fusion Adaptive Resonance Theory (ART) (Tan et al. 2007) inference engine so that they could make decisions proactively in response to events happening in the virtual world around them. In addition, they utilize the Natural Language Understanding module to analyze user's intention and the Natural Language Generation Module to translate the chosen response into natural text for presentation.

Subjects will be randomly assigned to one of the two experimental conditions – control (E1) versus treatment (E2). The 3D virtual world environment can be accessed through the internet browser and is modeled after a university campus and populated with NPCs in terms of look-and-feel, functionalities and services. The scenario for subjects is that they are looking for an overseas university for an exchange program and are visiting a virtual campus to help them in making the decision. During the experiment, each subject will be asked to complete a quest, where they will experience the key places of the university campus through the quest. The quest involves finding five check-points on campus where the clue to each check-point is given at the previous check-point.

Research procedures

Subjects participate in the experiment in a computer lab. They are provided with a set of detailed instructions on the experimental procedures. Before the experiment begins, the experimenter conducts a short tutorial session to familiarize the subjects with the basics of the environment and how to perform basic functions such as walking, talking and using maps to navigate in the virtual world. After the tutorial, the subjects are asked to carry out the experiment by completing the quest given to them. For subjects in the E1 (control) condition, they complete the quest by navigating around the virtual world with the help of a campus map in the system where they could use the map to check up information on different parts of campus and teleport to the respective checkpoints. For subjects in the E2 (treatment) condition, in addition to being provided with the campus map (as in the E1 condition), they are offered the assistance of intelligent autonomous NPCs that have the ability of performing autonomous behaviors; moreover, since these NPCs are embodied with a Natural Language Processing module, they can understand input sentences in a flexible way. They can even tolerate some typos if these are not keywords. Hence, subjects are able to interact with the intelligent autonomous agents in the form of NPCs to request for and obtain the information they need to complete the quest. Because the NPCs are autonomous, they could even offer teleport to specific locations requested.

After subjects have completed the quest, they are required to fill out a questionnaire to assess their experience. This questionnaire captures various aspects of user experience including social presence, perceived interactivity, and user enjoyment. The system also captures the amount of time taken to complete the quest.

Measurement

The items used to measure social presence are derived from Nowak and Biocca (2003) and Animesh et al. (2011). The scale for measuring interactivity is adopted from Animesh et al. (2011) and Mcmillan and Hwang (2002), and the scale for measuring enjoyment is adopted from Nah et al. (2011). The items are captured using a seven point Likert scale where 1 refers to strongly disagree and 7 to strongly agree.

Subjects

Subjects will be recruited from an intro to MIS class at a large Midwestern US university. In line with the institutional board review requirements, participation in this study is voluntary and will be compensated with extra credit for the course.

Data Analysis

We will carry out factor analysis to assess the convergent and discriminant validity of the measurement, and use multivariate analysis of variance (MANOVA) for the data analysis.

Expected Contributions

Virtual worlds are gaining in popularity and importance in various contexts while agent technology has been heavily employed to prompt the complex adaptive systems. While researchers in computer science are focusing on adding features to these agents to make them more intelligent, to the best of our knowledge, no systematic empirical work has been carried out to assess whether the use of intelligent agents can improve user experience in the virtual world.

More importantly, we are interested to test if media naturalness theory holds in the context of intelligent agents that function as NPCs in the virtual world. Specifically, we would like to present insight into whether incorporating intelligent NPCs into a virtual world can enhance user experience by increasing interactivity, social presence, and user enjoyment. If these three important features are fulfilled during the experiments, it may have significant practical implications. It provides a fundamental principle that through the use of intelligent agents that offer assistance to users in a more natural way than traditional means, user experience can be improved. In this way, virtual world designers and computer agent researchers would be aware of how intelligent agents could improve user experience. In terms of theoretical contributions, this study applies Media Naturalness Theory to assess the efficacy of computer agents in the virtual world.

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