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Toward Natural Selection in Virtual Reality

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Computer games, including massively multiplayer virtual worlds (MMVWs), populate the entertainment arena of the consumer market. Inexpensive and mass produced, computer games now have a level of visual realism approaching cinematic quality. The amount of 3D content in MMVWs exceeds what you could explore in your lifetime.

Unlike computer games, VR applications require expensive hardware and customized software and are installed for limited audiences. Maintaining and upgrading VR systems is also difficult. In addition, the virtual content's visual quality and extent are typically lower than in MMVWs.

Nevertheless, one feature makes VR systems stand out from other synthetic environments: a remarkable sense of presence, delivered by full visual immersion and motion tracking with proprioceptic feedback. The ability to make users believe that they actually "are there" has made VR a tool of choice for space, military, medical,[1] and other extreme-condition training applications.[2]

Here we describe a vision of VR games that combine the best features of gaming and VR: large, persistent worlds experienced in photorealistic settings with full immersion. For example, Figure 1 illustrates a hypothetical immersive VR game that could be developed using current technologies, including real-time, cinematic-quality graphics; a panoramic head-mounted display (HMD); and wide-area tracking. We also examine the gap between available VR and gaming technologies, and offer solutions for bridging it.

VR Games

Games are already entering what used to be exclusively VR territory by incorporating elements of body tracking into user interface controls. The Nintendo Wii's remarkable success underscores the value of physical interactivity in gameplay. Another example of body tracking in games is the Sony EyeToy camera, which spawned a family of games utilizing user body motions. Recently, Microsoft announced Project Natal for its next-generation console games, featuring a direct user interface employing natural gestures and voice.

VR technologies are also experiencing steady growth in both high-end and inexpensive systems. Optical trackers can cost as little as a webcam, and cover a few feet of tracked area. High-end trackers, such as WorldViz's PPT (Precision Position Tracker; www.worldviz.com/products/ppt) can capture user motions in a 50 × 50 × 3 meter area, with submillimeter precision. HMD technologies are also advancing rapidly. One recent example is Sensics' lightweight xSight HMD, with a resolution of 1,920 × 1,200 pixels per eye and a field of view up to 120 degrees. This headset weighs only 350 grams, making it suitable for fast-action gameplay.

As the examples in this section show, there's mounting evidence, from both industry and academia, that immersive gaming solutions provide a better platform for many types of interaction in 3D worlds.

First Implementations of VR Games

Hardware advances have made VR components available to a wider audience of researchers and practitioners. A VR system that cost over US$200,000 10 years ago now costs one-tenth of that or less. VR equipment's increased availability has stimulated the creation of novel applications, especially augmented-reality (AR) applications, which superimpose virtual content over a real environment. Examples include the Human Pacman game[3] and the Georgia Institute of Technology's AR Second Life (http://arsecondlife.gvu.gatech.edu), which bring 3D avatars into real environments.[4] In the AR Façade game (www.cc.gatech.edu/projects/arfacade), players interact with a virtual married couple in a physical apartment, using speech and unconstrained body movements.

New Devices for VR games

In 2008, NeuroSky (www.neurosky.com) introduced the MindSet (see Figure 2a), a wearable device that might become an icon for the integration of gaming and VR. The MindSet has sensors that read and analyze the player's brain activity in real time. A software development kit lets developers

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build brain-computer interfaces (BCIs) to translate player intentions into game actions. Several gaming companies, including Square Enix, have created technical demos for this device, which were presented at the 2009 Game Developers Conference. The MindSet communicates wirelessly with a host computer, making it particularly attractive for VR applications. Emotiv Systems' (www.emotiv.com) Epoc headset (see Figure 2b) is a similar product. As these examples show, the hardware components and user interface techniques have increasingly been growing together.

Nevertheless, VR equipment still costs too much to be a gaming platform for general audiences, deterring game developers from adding VR components to game engines. For example, the game engine CryEngine2 has no option for stereoscopic rendering, even for mid-range HMDs with a single viewport (such as the V8, eMagin, and nVisor SX). High-end HMDs, such as Fakespace Labs' Wide5 and Sensics' piSight and xSight series, require multipass and tiled rendering, respectively, making them difficult to integrate into most gaming engines. In fact, most rendering effects that make the CryEngine2's output so visually appealing are designed explicitly for a single-camera, single-viewport configuration used in desktop displays. The gap between games and VR might still be too large to justify efforts to make game software VR-compatible.

To bring games and VR closer, we suggest a new approach to game design that addresses many issues related to VR equipment's limited availability.

Figure 1. Using VR equipment, players would be able to use natural body motions to "walk" (or maybe swim) into this scene for close-up interaction and 360-degree immersive viewing. (Sources: Blue Mars Project by Avatar Reality, Inc. [background image] and Sensics [head-mounted display photo]; used with permission.)

Figure 2. Brain-computer-interface headsets: (a) the MindSet and (b) the Epoc. These devices let players translate their intentions into game actions directly, bypassing traditional input devices such as a mouse, joystick, or keyboard. (Sources: NeuroSky [2a] and Emotive Systems [2b]; used with permission.)

Making a VR Game

The "everyone plays" business model, adopted worldwide by the gaming industry, created a standard environment, which includes a PC or a gaming console and a TV set. To bring VR into play, we propose extending this model to "everyone plays at home, and advancing players also play in VR."

Because developing a full-length VR game for general audiences seems impractical from a business standpoint, we suggest reducing VR-playable content to short episodes and making them available to selected players. Our proposed game design has two key elements: *pockets of virtuality* (*VR pockets*) and *natural selection among players*.

Pockets of Virtuality

With VR pockets, users can play selected episodes of the game using immersive VR equipment: HMDs, motion trackers, and other immersive control devices. VR pockets embed a game at appropriate times in the storyboard, particularly when close-up interaction with the virtual environment will likely enhance gameplay. A VR pocket could be an entire game level or a minigame in a level. For example, one level of a MMVW could show a carnival scene, with players walking around and using different attractions. Some of these attractions might be VR-enabled, such as a Whac-A-Mole game, which lends itself exceptionally well to VR implementation (see Figure 3).

VR pockets could also function as *cut scenes*, noninteractive sequences often prerendered for higher visual quality. Game designers often use cut scenes to give players more information about the story or to reward them with a ride through beautiful scenery. With the advent of photorealistic real-time rendering, players can interactively experience cut scenes through an HMD and head tracking. VR pockets could be selected content in

Figure 3. A Whack-A-Mole VR game in an episode of *The Irresponsible Captain Tylor*. (a) A person playing the game, using a tracked hammer and a head-mounted display; (b) the first-person view of the playing field. (Source: The Irresponsible Captain Tylor TV © Hitoshi Yoshioka / Kadokawa Shoten, Tylor Project. Published by Right Stuf, Inc.; used with permission.)

locality-based gaming. For example, certain islands in Second Life could be exclusive VR locations, accessible only from VR-enabled clients.

VR pockets could take gaming to high levels of realism and engagement, which could generate significant public interest in VR games. This will raise the issue of organizing continuous, fair public access to VR resources. Our solution is natural selection among players.

Natural Selection among Players

In biology, natural selection ensures that only the fittest organisms survive, reproduce, and pass along heritable traits. Similarly, you could consider online gamers to be a collective body of individuals, governed by natural-selection rules in which only the most successful players advance to the VR part of the game.

Although VR hardware's availability is increasing, the number of concurrent players will likely exceed the number of VR gaming stations. Natural selection will help balance demand and supply for this limited resource. The underlying principle is simple: everyone plays on a desktop system, and advanced players can also play on VR gaming stations. The natural-selection mechanism must have three components:

- A game-specific merit-based scoring system, designed to motivate players to learn and practice the skills and concepts needed to access the VR part of the game.
- The number, location, and current progress of all registered players. This information will help the system estimate how many people will soon earn "VR status."
- Information on the number and status of all VR installations of the game.

The game will continuously monitor data related to the second and third components and update the requirements for playing in VR. The scoring system might also quantify how much time the user can spend in VR.

Alternatively, players might be able to purchase VR access using real or virtual currency. This practice could coexist to a variable degree with the merit-based scheme.

VR Gaming Stations

Arranging public access to VR gaming stations will depend on the nature of the game and the target audience. For example, for online first-person shooters, novice players will begin the game at home. After earning VR status, players will be able to continue the game at local arcades. For educational games developed for schools and colleges, advancing students will have access to VR gaming stations installed and maintained on campus. To motivate students, game progress could be linked to academic credits. Natural selection will ensure that there are no long lines at VR booths.

VR gaming stations could be also set up at scientific conferences or special-interest-group conventions, especially if these events are colocated with trade shows of VR hardware manufacturers. Government agencies with VR research and training facilities, such as NASA and the US Army, might provide support for developing and hosting VR games for recruitment and training, which we discuss in more detail later.

Proposed VR Games

As attractions in the upcoming Blue Mars MMVW, Avatar Reality (www.avatar-reality.com) is developing several minigames, some of which are well suited for VR implementation. Although Blue Mars is designed for PCs, these minigames provide a good illustration of what VR pockets might look like.

Multiplayer Golf

This game (see Figure 4) will require tracking the user's head and hands to provide sufficient control for making a perfect swing. For traveling on the golf course, the VR version of the game might

employ a virtual golf cart, using a point-and-go steering metaphor.

An Adventure Ride

In this attraction (see Figure 5), users must pass through multiple shining rings of light, traveling in an amphibious flying vehicle. During the ride, players try to avoid colliding with various life forms and other players. For a VR implementation, this attraction requires only head tracking. Players can use a keyboard and mouse to control the vehicle.

Gameplay Limitations

VR pockets will provide a limited duration of gameplay, perhaps between 10 and 30 minutes. Players will spend this time at the VR gaming station (not on the streets or elsewhere), fully immersed via an HMD and tracking equipment. One reason for the time limit is that prolonged use of an HMD could cause cybersickness. In addition, the equipment shouldn't be taken from the gaming station. So, we advocate purely VR solutions here, not AR, as in Human Pacman.

Serious Applications of VR Games

Besides offering a rich palette of entertainment applications, VR games could serve as a platform for selecting and training individuals for working in extreme conditions.

One high-profile opportunity is the expected launch of a human crew to Mars. In 2007, NASA announced a mission tentatively scheduled for 2028. Players who are now 7 and 8 years old and just starting to explore their first online worlds could be crew members.

Because of the crew's limited size, all members will need exceptional skills in many fields, from engineering to medicine and applied psychology. With help from scientists and educators, VR games can offer unmatched capabilities for such training.

Using satellite data, developers could reproduce selected areas of the Martian terrain in 3D, for previsualization, planning field trips, or practicing landing procedures by pilot trainees. The terrain data could also help train the crew to ride Mars rovers in simulated environments, monitoring the fuel level, driver fatigue, and water and food consumption during these exercises.

Immersive VR could help assess psychological compatibility between crew members by using digital-cloning technologies that are widely used in Hollywood. With digital cloning, future crew members could improve their personal bonding in VR while being physically separated.

Figure 4. The golf course on the Blue Mars virtual world. This game is well suited for implementation in fully immersive VR. (Source: Avatar Reality; used with permission).

Figure 5. An adventure ride around waterfalls on Blue Mars. This game is also well suited for implementation in fully immersive VR. (Source: Avatar Reality; used with permission.)

Emergency medical procedures, such as cardiopulmonary resuscitation and triage, can be practiced in VR, perhaps even better than in physical reality. This is because VR settings allow superior flexibility in modeling medical conditions and surrounding environments.[2]

VR Games' Social Impact

VR games could make major contributions to public outreach, research, TV culture, and social networking.

Public Outreach

Using VR games for training lends itself well to public education and educational outreach. NASA has been using VR for preflight activities since the mid-1990s. NASA could allow casual visitors into its training centers to observe astronauts training with a virtual game. Visitors could see what the immersed astronauts are visualizing. The trainees' experience could also be broadcast on commercial television, which would help popularize both the upcoming space mission and the VR game.

VR Games as an Academic Resource

Significant VR and AR research has concentrated on building VR applications and creating content for them such as 3D models, avatar characters, and animation. A standardized 3D immersive environment, open for local customization, would greatly reduce such development costs. In the academic community, Second Life has become a popular platform for research on social interactions in nonimmersive environments because it comes preloaded with massive amounts of content and a ready-to-use avatar control system. A similar standard would greatly aid immersive-VR research.

We're encouraged to see the growing interest in persistent virtual worlds from both public and commercial funding sources.

VR Shows and Games on TV

Reality TV is another candidate for VR. In Korea, gaming has become so popular that gaming contests run on prime-time TV. Public interest in VR gaming contests might be at least as high.

Social Networking

Video games have already surpassed motion pictures in monetary value. Still, going to the movies is common for young people seeking social contacts. Movie theaters provide a neutral territory where the different parties can feel safe and comfortable in a public setting. Attending movies also gives people a chance to share an experience for later conversations.

Can VR games offer a new media for this purpose? Imagine that instead of being passive watchers in a movie theater, people can share an interactive immersive adventure in a VR parlor—for instance, exploring virtual Venice or Paris or any other place they choose. Using BCI headsets, the players would have the opportunity to directly communicate on an emotional level.

Gaming technologies and VR have been increasingly adopting each others' technological and social features. However, creating a VR game remains problematic owing to the challenges of conventional business practices in game production. Intense competition in the gaming industry allows little room for creating applications that don't immediately improve gameplay for the intended audiences.

Nevertheless, we're encouraged to see the growing interest in persistent virtual worlds from both public and commercial funding sources. Last year, NASA announced a call for proposals for designing and developing an massively multiplayer online game that would draw public attention to space exploration. In spring 2009, NASA selected two projects for further development (http://ipp.gsfc.nasa.gov/mmo). In March 2009, serious-games company Firsthand Technology received a $3.4 million US National Institutes of Health grant for developing and evaluating the effectiveness of VR health games for children (www.firsthand.com/publications).

Perhaps a mixture of funding strategies, from both government institutions and private investors, will provide the impetus for additional development of massively multiplayer VR games that combine the best features of traditional computer games and VR.

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