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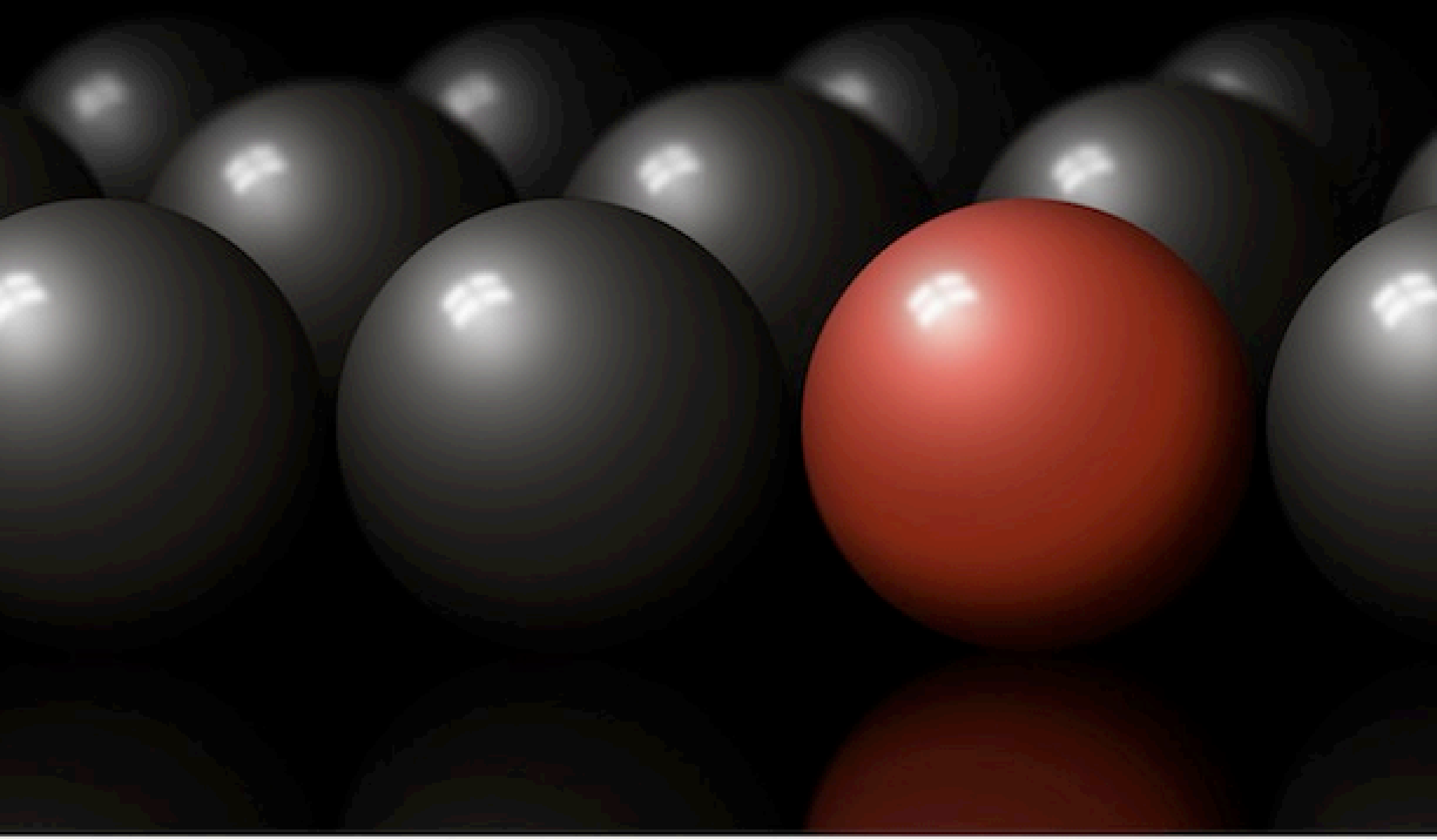

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Applied Virtual Environments: Applications of Virtual Environments to Government, Military and Business Organizations

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Abstract

Virtual environments (VEs) such as Second Life or World of Warcraft can be more than entertainment; they also offer new ways to test concepts and prototypes, train employees, and anticipate actions of an opponent. The U.S. military and other government organizations are applying VEs to support achieving training, operational, and rehearsal objectives. Business enterprises are starting to use virtual realities to lower costs and increase capabilities. This paper provides a systematic characterization and analysis of the features of VEs that improve organizational effectiveness. The paper describes: first, the key elements of a virtual world; second, the Use Modes or methods by which virtual worlds can be used to achieve a wide range of business or military objectives; third, a categorization of the wide range of application areas to which VEs can be applied; and lastly, the current limitations, emerging opportunities, and future research recommendations for using VEs to achieve organizational objectives.

Keywords: Government, Business, Military, Computer-supported collaborative work, Virtual reality

Scope and Overview

This paper focuses on the longer-term potential organizational uses of virtual environments. We extrapolate from current and near-term capabilities provided by virtual world technologies that are still in their infancy, and from the VE application areas that can be applied today. To keep the scope of the paper practical, all the technologies discussed are within the realm of current technology, but are technologies that have not yet been applied to virtual environments in the ways that we argue are possible. This work defines the key elements of a VE, briefly outlines the top-level Use Modes of VEs, reviews the application areas in which organizations could apply VEs, lists the current technological limitations, and recommends future research activities.

Note that we use the term virtual environment and virtual worlds interchangeably, except where explicitly noted in the text.

1. Background

Virtual environments (VEs) or virtual worlds are usually online three-dimensional (3D) simulations that allow participants to observe and interact with an environment through an available set of actions. A world is a predefined, bounded virtual 3D space that keeps the participants within those bounds so as to be able to manage the computational requirements and balance the computational loads. Until recently, only one server (which could handle many users' computers) had been responsible for one world within a larger VE, and that physical reality has limited the number of participants and non-participant objects that could be active in a given world at a given time. In the near future, virtual environments could have pieces operating across thousands of computers in a collective computing process called *cloud computing*. Even so, while the number of active participants and the range of possible interactions will be much greater than today, there will always be some limit on how many elements can be present and active in an environment at a given time.

Virtual environments are flexible realities. Because physical transport between each of the worlds within a VE is nearly eliminated, participants can rapidly transfer from one world to another, either by explicit *teleporting* as in participant-built Second Life, or via specific entry and exit points as in the commercial game World of Warcraft. Depending on the purpose for which the VE was designed, one can arrange its various worlds as either being completely independent of each other and dramatically different, or as extensions of one another as part of a larger coherent environment.

Participants participate in a VE as a creature called an *avatar* that can be human-like or otherwise. As the human participant hits keys or moves a mouse, the avatar performs the actions commanded. The participant can see the virtual world in several ways. One way, called the *first person view*, is to look through the eyes of the avatar. In this view, the avatar is not seen by the participant, much as we do not see ourselves. Conversely, the participant can use the *camera view*, where the participant watches the avatar act for them as if viewed through a floating camera behind or to the side of the avatar. Usually the participant is looking forward from behind the back of the avatar's head. The camera view can also be set to move independently from the avatar, scanning the wider world while the avatar does something already commanded, such as walking.

Communications in virtual worlds are also becoming more similar to the way humans communicate in real life. VEs originally only used text message exchanges much like chat rooms for both participants and computerized creatures in the world. These text comments were displayed over the head of the speaking avatar or in side panels.

More recently, in-game communications have become more similar to real world communications. Audio-based applications now allow participants to use microphones and speakers to talk with other participants just like a group telephone call. These communications applications are either provided by the VE provider, or can be installed by users as separately installed applications. These applications generally use Voice Over Internet Protocol (VOIP) and include services such as Skype, Ventrilo and Teamspeak. These communications can also be further subdivided into channels, where groups can make their communications secure amongst their own members.

In contrast to text-based communications, the more natural audio communication among participants further blends the natural visual and audio senses of the participant in the VE, making the action feel very real. (Schilbach et al., 2006, pp. 718-730) The near-instantaneous matching of stimulus, action, and response through coordinated visual and aural cues enhances the cognitive experience of the participants, thereby making the actions seem more real. (McCabe & Castel, 2008, pp. 343-352)

Future VEs may exploit whole-body game control mechanisms such as the Wii, making VEs even more similar to real life. Instead of using a mouse or keys to move the avatar, a participant will have the modern equivalent of goggles, microphones, speakers, and wireless transmitters on all appendages. (Kelsey, 2009) With these new tools, the individual will not be peering at the new world through a computer or TV screen, but rather walking, talking, and acting—even building—as though the virtual world was in fact the real world. (Schwartz, Gupta, Anand & Kavetsky, 2007) In short, current VEs are evolutionary steps to much more robust VEs with all the flexibility and drawbacks of real life, if realism is the purpose of the virtual world.

The closer the virtual world resembles a physically possible world recognized by the human participant, the more the virtual world's images tend to stimulate all the senses and evoke sensations and even feelings in the participant as if they were physically in that part of the real world. (Lombard & Ditton, 1997, p. 20) Combining first-person view, natural communications, and full-body interfaces, the relationship between moving the avatar and the participant feeling as though the VE is real may soon become a reality. (Moore, Ducheneaut & Nickell, 2007, pp. 265-305) (Van Vugt, Konijn, Hoorn, Keur & Eliëns, 2006, pp. 267-80)

2. Ground Rules of VEs

The ways in which participants may interact in virtual worlds is limited only by the design of the world, not by the rules of physics. For example, in Second Life, a participant can fly, walk through walls if they possess proper objects, and teleport to other worlds via objects carried or available in the environment. In some fantasy worlds, different physics rules allow the apparent use of magic. Conversely, a virtual environment designed for military training does not allow unassisted flying, walking through walls, teleporting, or magic. (Kenny, et al., 2007) The ability to apply or relax the laws of physics is a critical factor in selecting the Use Modes for VEs, as described below.

Freedom of action in a VE is based on the amount of creative latitude the designers give to participants. Two general categories exist today: co-authored worlds such as Second Life, or commercially designed worlds such as World of Warcraft or Everquest 2. In co-authored VEs, individuals download a program that allows them access the world, and then may use tools inside the world to create something that is not specifically designed by the operators of the VE. These creations could include buildings, landscapes, clothes for themselves or other avatars, or dune-buggies and motorcycles. A participant can even pay to own some space on a server, and then make the rules for an island or a building, determining who can enter and how.

In contrast, a commercially designed VE is usually richer in visual and contextual graphics because the look and feel of the world is not dependent on the time and skills of the participants. Usually the world and its rules are programmed in advance by salaried designers working for the VE-providing organization. Participants usually need to purchase and install a program on their local machine, and also pay for continuing access to those servers. The designers are the authors who make changes over time as the game evolves, often on the basis of participant requests. Online games epitomize this category. For example, any participant in Everquest 2 can pay a monthly fee and then scale any accessible mountain in Everquest 2, but they cannot create a mountain or a hut in a village. Conversely one can pay to buy the land and create a hut in Second Life, but one cannot enter all the huts or scale any mountain unless someone else built them and allows visitors.

Interim worlds between design and co-authoring are now emerging. One such world is a game is called Spore. Its distinctive co-authoring option is the creation of creatures. Participants can create their own creatures, which are then added to that server space as well as to the individual participant's account. Other participants using different accounts can then interact with these creatures. These actions could include fighting and killing the new creature. If this happens, the new creature is eliminated from the other accounts. However, the creature continues to exist for the participant who created it until that person deletes it. The likely future evolution of virtual worlds is to provide greater creative flexibility among participants. (Hong, Looser, Seichter, Billinghurst & Woo, 2008)

VE software is available from commercial sources or from open source repositories. VEs can be set up to be accessible over the Internet or behind a firewall for more privacy. For example, Government organizations will want to keep sensitive or protected information available only to authorized personnel. In a similar manner, companies that do not want their proprietary information exposed to the world may create a private VE behind a firewall that allows participation only by selected employees.

Organizational needs will determine which features of reality should be represented in the VE and which should be violated in order to best achieve the application area's objectives. In some cases, using less-than-realistic VEs can better achieve training objectives or educational objectives for less cost than trying to represent actual reality, as described below. In other cases, a very close approximation of reality is necessary. For example, organizations with strong no-fail rules such as medicine, air transportation, testing, or many military missions need a high level of realism. (Wilson, 2008)

3. Key Elements of Virtual Environments

Virtual environments offer choices across key features. By selecting VEs with certain features, organizations can better achieve their application objectives. We first describe the features, then categorize the four types of Use Modes of VEs. We then describe the application areas with examples of how the features and Use Modes of VEs can be combined to best achieve application objectives.

3.1 Alternative Physical Rules

As mentioned above, it may be preferable to strictly apply the laws of physics to a virtual environment, or to relax one or many physical laws to achieve the objectives of an application. The ability to fly or teleport is not desirable in a tactical military training exercise, but may be desirable in an application to violate selected physical laws in order to support the achievement of other training objectives. For example, the underground gas tank and pipe testing firm Crompco Corp. created a virtual facility where participants could see though the ground to view the layout and functioning of the underground tanks and pipes. Crompco's Head of Technology said that "It's great for training new hires and showing changing regulations to existing employees." (Hof, 2006b) The one violation of the law of physics was to be able to see underground, but this was essential to achieving the training and education objectives.

3.2 Shared and Collaborative Environments

One advantage of virtual environments is that they provide participants with a shared environment. Shared experience is a prerequisite (but not a guarantee) of improved group cohesion. Shared experiences improve future communications by providing a common knowledge and experience base. Moreover, virtual environments provide the ability to be more inclusive of physically challenged or handicapped persons in a group exercise. Shared environments are also useful for creating and instituting a new culture for an organization, or reinforcing an existing culture. Moreover, these shared environments can be provided remotely and across different time zones, thereby reducing travel time and costs.

Shared environments inherently bring new possibilities to collaboration. The degree of interaction allowed among participants and with the shared environment will determine the degrees of freedom allowed in the collaborative effort. For example, if the participants are allowed to make modifications to their environment, they are literally “co-authoring” the shared environment.

In general, each individual has their own *mental model* of the problem and the solution space. If each participant can add their individual mental models to a single combined VE, they can resolve the differences between the models and subsequently play out the combined VE that represents the team’s best understanding of the situation. This combining of individual mental models into a shared mental model is critical to successful adaptive problem solving. (Klein, 2009) Moreover, the team is not restricted to playing it once, but can replay it many times, with various changes as time and resources permit. This kind of continuous refinement enables greater use of existing organizational knowledge, and can improve team cohesion and resilience to addressing new and unexpected situations. (Comfort, Boin & Demchack,)

This collective sharing and playing through of solution options can be performed in a cooperative way, or in a competitive way. Splitting a team into competing groups can reveal options and insights not available from a single team. The more degrees of freedom in VEs, the more flexibility available to participants to collaborate or compete.

Overall, achievement of some application objectives is better served by restricting some abilities to modify the VE via co-authoring methods, while others are better served by providing more freedom of action, especially in brainstorming-type collaboration.

3.3 Synchronous and Asynchronous Sharing

Participants can share VEs simultaneously, or can leave artifacts for other participants who will arrive later. Such artifacts may include messages or instructions, or may include replays of what the earlier participants did. Leaving a record of previous activities may be intentional or unintentional on the part of the first participant, depending on the purpose of the application. For example, a researcher may want to replay participants’ activities at some time after the original participants have left.

3.4 Partially Shared Environments

Participants can overlap in time and space for the whole event, or may enter or leave during an event. By using alternative channels, the messages each participant sees and can send may vary from participant to participant depending upon permissions. Extending this capability to the future, what each participant sees of the environment and of each other and their artifacts may vary among participants. This will also be an essential capability for providing playbacks of previous events while the same avatar is presently viewing the playback, as would be required for an After Action Review. Being able to see all sides in an After Action Review after a training event can provide better learning than just having experienced one's own side in the training event.

3.5 Extensive Drill-down Capability

Expanding on the concept of seamless transfers from one world to another, one could define the different worlds to be a different view from each echelon in an organization, whether government, military or commercial, or at different levels of detail for educational purposes. For example, a tactical unit could have its view of the operation, while the view from two echelons higher sees a different but related set of factors upon which it will base its decisions. This type of sharing of experiences across echelons helps participants better understand the strengths and limitations available at each echelon. This capability would be particularly useful in an education or experimentation setting, and might also be useful in mission rehearsals.

3.6 Time Compression Capability

Currently, VEs run at real time or wall clock time because of the human participants. In the future, VEs will have the ability to run slower or faster than real time in order to meet the objectives of an application area. For example, *what if* analysis may want to run ahead by a month using only computer-operated avatars to see how the world evolves in an experiment. It may also be possible to let human intervention occur at specified decision points in the time compression, or when certain conditions in the environment are reached.

3.7 Potentially Continuous Availability

VEs can be running 24/7, and if participants *have a plan* for how to use the environment 24/7, the VE will be available. This can be useful for a business that is operating in many different time zones, or for different shifts in a government or military organization, whether co-located or physically distributed.

Except for selected types of individual training or education, none of the applications described below are *drop in* activities where participants come and go as they please as in World of Warcraft or Second Life. Each application area has objectives, and organizations must have a plan both for how to achieve those objectives and for how to confirm the achievement of those objectives. In a similar manner, participants must be briefed on the context, presented with a history leading up to the event, and their own in-mission objectives in order to meet the application's objectives.

4. Methods or Top-Level Use Modes

We define a Use Mode as a set of rules that apply to the VE and the perceptions of its participants. The VE creator selects the degree of reality (strong or loose) and the degree of perception filtering for the participants to achieve the application objectives. These rules usually do not change during execution, but there may be good reasons to vary the rules depending on the objectives. For example, in an After Action Review after a training event, the perception of the participant may be shifted from the friendly side perspective to the enemy side, or even to the controller's view, in order to better understand what occurred.

In general, there are four top-level "modes" in which to define a VE to support achieving an application area's objectives:

- Representing Reality

- Representing Enhanced Reality
- Representing Echelons of Reality
- Representing Perceived Realities

4.1 Representing Reality

In this mode, the purpose of the virtual environment is to provide an environment that matches reality as closely as possible. For example, the Virtual Battlespace 2 (VBS2) military training environment is a very good representation of an urban environment in which military training objectives can be achieved. (Caselden, 2009) In such worlds, the laws of physics apply, and participants cannot fly without assistance or walk through walls. Moreover, the camera view is restricted to first person, or locked on top of the avatar, and no more information is provided to the participant than would be available in the real world.

4.2 Representing Enhanced Reality

Enhanced reality involves providing additional information to the participant that would not be available in the real world, but facilitates the achievement of the application's objectives. For example, seeing through the ground was essential to meet the training objectives of Crompco Corp. as described above, and similar enhancements could be useful in training first responders. (Werner, 2008) Another example would be allowing mechanics the ability to see through a new piece of equipment to better learn how it works and how to maintain it. A drug manufacturer might allow drug developers the ability to see and manipulate protein chains without regard to time, space, or physical manipulation abilities while they investigate options for new organic compounds.

The key to selecting a properly enhanced reality is to determine which laws of physics need to be violated in order to achieve the application area's objectives, while leaving the rest of the laws intact. It might also be useful to be able to switch on and off selected laws, thereby letting the VE provider or the participant change the laws that apply, depending on the application area's objectives.

4.3 Representing Echelons of Reality

Representing echelons of reality exploits the feature of VEs to connect worlds that have some overlap, but are viewed at a different echelon of decision. For example, a battalion will have a detailed view of its own situation, but its brigade headquarters will have a view of that battalion that is much reduced in detail. Conversely, the battalion headquarters view does not see everything the brigade headquarters does, but could receive situation maps and orders from the brigade. Unlike most existing VEs that are all at the same level of resolution or detail, echelons of reality allow for different views of the same reality at different levels of detail, where the level of detail is defined by the echelon of military command, government hierarchy, or business management.

All types of large organizations require the successful coordination of actions from the lowest to the highest echelons. The ability to represent the same situation as viewed by different echelons can help participants at each echelon better understand what is happening, should be happening, or should not be happening at any given time. For a large commercial company, it is useful to educate employees as to how all of the parts fit together as viewed from other parts of the company, as was described in *The Great Game of Business*. (Stack, 1992) The ability not only to see these different echelons and perceptions, but also to be able to quickly shift from one to the next, will provide a great advantage to the participants, depending on the application areas.

4.4 Representing Perceived Realities

The proverb, "You never truly know someone until you have walked a mile in his shoes" can also be applied to, and achieved in, virtual environments. VEs have the ability to represent how each faction—friendly, enemy, neutral or wavering—sees its situation. This ability is useful for educational purposes, building group cohesion, and for purposes such as Red Teaming where part of the friendly Blue Team acts as an opponent to identify weaknesses in the Blue Force. Seeing what you can see and seeing what you think others can see can be essential to planning national level Strategic Communications and other Information Operations.

One useful exercise is to have one participant create their view of a particular situation, have someone else create one for their situation, and then swap views by visiting the other's VE. This can create substantial insight into the thinking processes of others, and can be beneficial in improved cooperation as well as an advantage in competition.

There is always a problem in terms of where one gets one's data and whether one can trust it. Even so, decision makers already make decisions in the face of uncertainty. A virtual world can help capture and codify assumptions about different perceptions, especially competitor perceptions. Moreover, having a VE allows many subject matter experts to enter, evaluate, and possibly modify the perceived opposing perceptions to improve the quality of those assumptions. For example, if one is uncertain about some data, it could be "grayed out" and made semi-transparent in the virtual world—an option not readily available in the real world.

These four Use Modes provide a way for the VE creator to select a version of reality that will best meet the application's objectives. Overall, the key to leveraging VEs is to understand and exploit the fact that they do not have the limitations of reality unless you *want* them to have those limitations. By matching the application objectives to these four modes, the VE provider can then select the specific VE features necessary to achieve those objectives.

5. Application Areas

We now provide examples of how VEs can be used to support more traditional government, military and commercial application areas. The primary goal of any application is to accomplish its purpose. For example, a training event is designed to achieve training objectives, while a rehearsal is designed to provide pre-experience to those who are about to perform the real event. There are many ways to exploit VEs for each application. Moreover, the achievement of the objectives may be better facilitated by using VEs than by using more traditional means.

5.1 Organizational Presence

A number of companies and governments have created a permanent presence in some virtual worlds for advertising and other purposes, such as Sony, IBM, Nissan, and ABC. (O'Brien, 2007) In Second Life, the Swedish government has created the House of Sweden. (The Swedish Institute, 2009) Both the National Aeronautics and Space Administration (NASA) and the National Oceanic and Atmospheric Agency (NOAA) have an online presence and educational VEs in Second Life. (Linden Labs, 2009) Until recently, Coca Cola and Nike had meeting places in Second Life, and a number of other companies, such as Pepsi, GM, Toyota, Dell, CISCO, Sun, Microsoft, Intel and Apple still have a presence there as well. (Hof, 2006a) (Moore, 2010) Business recruiting has occurred in Second Life and other virtual environments. (Driver, 2008) (D'Angelo, 2009) (Rosedale, 2009)

5.2 Education

VEs provide a form of immersive education that can be applied to learning languages, cultures, or specific subjects. For example, Second Life includes a virtual education center represented as an eight-story building, where participants learn how to use the Second Life library scripts to build and tailor their worlds and avatars. VEs have been created to represent different ecosystems on the Earth, outer space, fantastic places, and other *what if* environments. VEs can allow the rapid shifting of connected viewpoints, such as different echelons in an organization, or the perceptions of other participants. While VEs have already been used for some educational purposes, we are just beginning to exploit the full potential of VEs for educational purposes.

5.3 Training

VEs have already been used for training by a consortium of companies that includes Wal-Mart Stores, American Express, Intel, and 200 other companies. (Hof, 2006a) VEs have been applied to individual and group training, and are applicable to teaching specific individual skills, as well as enhancing group cohesion. Training environments have included both VEs that represent reality as closely as possible, such as Army tactical trainers, and VEs that represent enhanced reality, such as the ability to see below ground at underground tanks and pipes. Emergency response training exercises are also likely to begin using VEs, which will likely include versions with a great deal of realism, and others that provide some enhanced reality features to assist in pre-event understanding and coordination. (Brooks, Fuchs, McMillan & Whitton, 2006)

5.4 Planning

Planning complex operations involves multiple organizations and often multiple environments. VEs could be used as a collaboration environment to help coordinate various elements in visualizing and understanding the strengths, weaknesses and tradeoffs associated with both the upcoming mission and the planning process itself. Planning, analysis, and education are the application areas where collaboration is currently most commonly used.

For a government or commercial organization, a VE could be created to represent the workflow as objects or rooms, and each avatar could move from one step to another in the workflow. Drill-down could be provided by the avatar entering the next step, which is a separate VE associated with the details of that step. At any time, that participant or the leader can step back and view the whole workflow and its status, and understand where bottlenecks have arisen.

VEs are also useful in representing alternative perceptions for supporting planning. For example, the Blue Team may have a view, while the Red Team has a different view. Being able to switch views and see what you think the other side sees is essential in planning Information Operations.

5.5 Rehearsal

Government, military and commercial organizations use rehearsals to improve the execution of key events. The military uses mission rehearsals to resolve problems in a planned mission before mission execution, and to provide *veteran experience* to those who will undertake the actual mission. There is also increased confidence provided to the unit when the actual mission unfolds very similarly to the mission rehearsal sequence of events. (Dick Rouse, personal communication, September 1997 regarding successful application of simulations as mission rehearsal for the liberation of Panama.)

Public institutions and commercial companies also use rehearsals, such as launching a new product or planning and executing a key event. VEs can provide a less expensive way to test whether everything will execute according to plan, and to highlight problems in the plan before the actual event. VEs can be used as *virtual sandboxes* constructed using real world data as populated by employees of the organization, thus capturing the knowledge base or perception of the situation as viewed by the organization. These sandboxes can then be used to rehearse or test plans and options, as well as contingencies when unexpected events occur. Participants can identify the options that are useful or unworkable in a safe testing ground. Since the simulated outcomes result in no real-world consequences, participants can afford to make mistakes and thus learn from possible misunderstandings of the emerging situation before facing it in real life. (Sommer & Loch, 2004)

5.6 Analysis

There are many forms of analysis, and VEs would be useful in supporting some of them. VEs are very useful in performing *what if* analysis even with current technology. One could also perform Red Team analysis in a VE, where one group creates that which they want to protect in the VE, while the Red Team goes after it to find vulnerabilities. Analysis that involves human interaction could be supported by VEs, but analysis that does not require constant human interaction would allow substantial time compression, thereby quickening the analytic process. VE-supported analyses can substantially increase opportunities for sensitivity analysis by being able to vary laws of physics or the perceptions of participants.

5.7 Experimentation

In an experiment, there is a hypothesis to be tested, and variations on the conditions to provide the analytic breadth. Since human participation is essential to most organization-based experiments, VEs are a likely candidate to support experiments. For example, an organization undertaking a business process re-engineering project will want to know if the *as is* representation is complete and valid, and whether the *to be* representation is feasible and provides the desired improvements. In a similar manner, government and commercial organizations may want to experiment with new concepts of operation. Similar experiments could be performed on new process or product rollouts. In more elaborate cases, experiments could be run on alternative social organizations or economies.

5.8 Test and Evaluation (T&E)

Each test has a set of objectives that must be met. For tests that do not require the physical object to be tested, a virtual environment could be used to support the testing at less cost than a physical test. In addition, when human interactions are required as part of the test, a VE provides an enormous benefit in the collection of data from the human participants. Of course, the degree of reality in a T&E environment must be fairly high in order to provide convincing test results.

5.9 Situational Awareness

Situational awareness could be enhanced by using VEs. Assuming that the information necessary to create the VE to support situational awareness exists and is available in the correct formats (which are two huge assumptions), one could represent past, present, or future situations from individual and organizational perspectives. For an example of past situational awareness, 3D simulations similar to virtual environments have already been used to re-create crime scenes, (DesignWare, 2009) terrorist attacks, (O'Brien, 2007) and aircraft disasters. (McWhertor, 2009)

As an example of current situational awareness, *annotated reality* or *augmented reality* displays have been developed that provide additional data displayed on top of a real scene. So if the shadowy figure on the ground display is not known to be friendly, it is annotated as being a neutral or hostile, similar to a heads-up display in a fighter aircraft.

As an example of future situational awareness, a real-time heads up display could be a component of a *what if* analysis, or of a test environment or training event. For example, if one is trying to train a computer network defender, having a virtual world representation of the network being defended, representations of the malware, and representations of the users on the network could be useful in allowing the network defender to visualize how they interact and spread either in real time, slower than real time (for better understanding) or faster than real time (for predictive purposes).

6. Current Limitations and Emerging Opportunities

Not all of these capabilities exist in current VEs, but there are no technological limitations to developing any of these features in future VEs. The modeling techniques necessary to implement these features exist, but the actual implementation of each does not. Designing and building these features into VEs will take time and resources. Nonetheless, these necessary tools and interest are developing in both commercial and noncommercial organizations.

Like any simulation, it takes time and money to develop virtual worlds and the objects or artifacts that populate them. Although *anything* is theoretically possible, the time and money required to create each part of *anything* must be considered when creating VEs. Reuse can help, but like any other simulation, reuse evaluation and tailoring reusable components costs time and money.

In addition, VEs also follow the rule of garbage-in-garbage-out. Unless the data is available to represent the Use Mode and its features adequately in a VE, then the outcomes of each application area may be misleading. For example, if a tactical simulator is supposed to represent reality, but there is a bug that allows the camera to be detached from the avatar to remotely view in a way not possible in reality, then the results of that training session would not be achieved. Participants often look for ways to *game the game* and gain unfair advantage, so unless the VE is protected from such misuse then the application's objectives will not be achieved.

VEs are also computationally intensive. Currently, each server has limits on the height of objects (like buildings), the ranges at which objects and avatars can see and interact, and especially on the number of objects that can be active in a world at any given time. While these limits have been steadily relaxed over time (e.g., the number of objects allowed continues to grow), there are still practical limits to how detailed the simulated experience can be in any given world. To expand the attributes of an avatar or the objects within the environment, each active object providing that attribute consumes CPU cycles and memory. Therefore, there are practical limits on the amount of depth or level of detail than can be provided in each VE. Even using cloud computing, each CPU will have a limit in terms of how much computation it can manage, even if those limits are much less constraining than they are today.

As described above, not all of the technology exists in VEs to support all the Use Modes and application areas described in this paper. For example, the ability to play back a previous sequence and still have the same avatars present to view the replay but not interacting with the replay has not yet been implemented. Even so, using different channels and different perceptions should allow these capabilities to be developed in the next few years if resources are allocated to their research and development.

Lastly, as with any other shared network, there are risks to being online in a shared environment. The most obvious risk is from hackers, who have already attacked Second Life and World of Warcraft with different types of denial of service attacks. (Lemos, 2006) There are also significant risks in putting proprietary or classified information on a server that is not wholly owned or secured by the using organization. While commercially available VEs are useful for a range of applications, the most sensitive data should be reserved for dedicated servers that are behind firewalls and controlled solely by the using organization.

Even when considering this list of current limitations, the opportunities for using the four VE Use Modes to support each application area continues to grow. Governments, companies and the military are all looking for cost-effective ways to achieve training objectives and the goals of the other application areas. Virtual environments, other non-VE simulation technologies, and computing horsepower gain substantially new capabilities each year. As a result, the technology to handle larger and more detailed VEs continues to grow, thereby reducing many of the apparent artificialities of current VEs.

The sheer number of individuals and organizations working on the advancement of VEs provides hope for the future. One goal of this paper is to help organize how these various efforts could be considered fitting into the larger vision as defined and categorized by the features of VEs, the Use Modes, and their application areas. In particular, adapting non-VE simulation technologies to facilitate all four Use Modes for VEs will contribute significantly to the achievement of the vision for VE capabilities and applications described in this paper.

7. Summary and Recommendations

This paper presented a set of VE features and their Use Modes in support of achieving the objectives of a wide range of application areas. The four main Use Modes of VEs are to provide as close of a representation of reality as possible, to enhance reality by allowing selected laws of physics to be violated, to provide different levels of resolution to demonstrate how different echelons of management levels view the same situation, and to provide perceived realities based on the perceptions of various participants.

Our three primary recommendations for the future are:

First, that the VE research community design and develop the features necessary to implement all four Use Modes, especially time compression, different echelons of resolution simultaneously, and different perceptions simultaneously. All of the technologies exist in more traditional simulations, but these legacy simulation technologies have not yet been incorporated into VEs. This will cost time, money, and skill to create, adapt, and use, but the potential benefits to large-scale organizations will be significant.

Second, that the VE community needs to elaborate and refine its knowledge capture techniques for organizations co-authoring VEs in a cooperative or a competitive mode. VEs will then be better able to provide organizations the ability to collectively capture knowledge embedded within organizations but not normally recognized or easily available for adaptive problem solving. With VEs properly integrated into the organization's processes, structures, knowledge requirements and social behaviors, the normal trial-and-error methods of organizational problem solving can be evaluated in a simulated environment that allows continuous learning and exploratory experiences without costly consequences. Moreover, these collectively experienced simulated events can be shared with others who did not participate in the original event. Stored for later retrieval and further refinement, they will constitute a growing library of knowledge that can be reused and refined by other members of the organization over time. (Author, 2003)

Third, we encourage large-scale organizations to experiment with the ways in which they can leverage existing VEs in the four Use Modes. When large-scale organizations experiment with exploiting these features to better achieve current application objectives, they will also generate opportunities to create new application areas not yet readily apparent.

Just because an envisioned VE is theoretically possible, that does not mean it will be built, or built in ways useful to any given organization. Even so, many organizations are trying to incorporate VEs into their operations. We are just beginning to explore and exploit VEs for real-world applications, but the future looks promising for both VE providers and participants across a wide range of organizations and applications.

Disclaimer

This work in no way represents the official position of the U.S. Government, the U.S. Navy, or the U.S. Naval War College.

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