Introduction

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1 Introduction

The recent boom of virtual online societies like Linden Lab's *Second Life* (see Linden Lab Inc., 2008) and *Google Lively* (see Google, 2008) shows that there are increasing numbers of potential users for virtual and augmented reality systems. The development of such Massively Multiuser Virtual Environments (MMVEs) poses new challenges on both distribution platforms and virtual reality systems. Addressing these challenges is a community-wide effort, necessitating the pooling of resources and experiences from both virtual reality and networking/distributed computing communities. To provide a bridge between these communities, we founded the Workshop on MMVEs (see Schiele et al., 2008) at the *IEEE Virtual Reality 2008 Conference*. This special issue reports on the content and results of the workshop and contains extended versions of selected papers. In what follows, we first describe what a MMVE is and present the main challenges when developing one. Afterwards, we give an outlook on future challenges and how some of our selected workshop papers address them.

2 Massively Multiuser Virtual Environments

A MMVE is a distributed virtual world that allows thousands to millions of users worldwide to interact in real-time with each other within a common simulated environment. The field originated with the US military's simulation network SIMNET (see Miller and Thorpe, 1995) in the early 1980s, and has advanced to commercial Massively Multiplayer Online Games (MMOGs) in the 1990s (e.g., World of Warcraft, Lineage, Everquest, EVE Online, to name a few). As an academic field, it is relatively

young and involves both the disciplines of graphics and networking. Both the names Distributed Virtual Environments (DVEs) and Networked Virtual Environments (NVEs) have been used to describe the discipline. However, as we feel that a common name should be adopted as the field matures, we have chosen the prefix *massively multiuser* to denote the main, and most attractive feature of such environments.

When developing an MMVE, some issues faced by developers include:

Consistency: MMVEs require users to participate in a shared environment that provides a sense of realism. User actions and behaviours thus have to propagate across networks and should be seen consistently among all relevant participants.

Interactivity: One characteristic of MMVEs is that they are very interactive. Users can almost act as if they are seeing or talking to each other in a face-to-face manner. Thus, delay among users, typically caused by latencies on their communication links, must be bounded. The actual range depends on the application type, but is often in the range of a few hundreds, or even a few tens of milliseconds.

Scalability: The main attraction of MMVEs are their scales, where a large number of users can participate in the same world, attending the same events or activities. Commercial MMVEs have achieved this with clusters of servers, whereas many current research work focus on a more distributed approach using the users' machines (i.e., in a form of peer-to-peer, or P2P networks).

Persistency: To provide a sense of realism, MMVEs differ from the traditional multi-player games or virtual environments in that the content, data, and user status persist across user logins. Users can come and go, but their data and impact on the environment is preserved and still seen by other users, or themselves during the next login. Such characteristic allows content to be accumulated, and also user footprints be recorded in the environments.

Reliability: MMVEs often need to operate 24 hours, seven days a week. Therefore, ensuring that the system functions despite of software or hardware failures, is another important aspect of MMVEs.

Security: Many MMVEs rely on commercial support, and allow trading or transactions to occur within the environment. To maintain order and user trust towards the systems, transactions, trades, and executions of the rules of the virtual world must be kept correctly and fairly.

This list is by no means exhaustive. Still, it provides a glimpse on the types and scales of the challenges that MMVE developers face. In general, an MMVE is a distributed simulation system that can be structured into three tiers: presentation, simulation and storage. Depending on the placement of these tiers on host machines, different system architectures have evolved. On one end of the spectrum are *centralised server-based systems*, which are adopted by most current commercial systems. In this architecture, a centralised server cluster contains dedicated servers for simulation and storage. The presentation is typically placed on the end user devices, leading to a classical multi-tier architecture. The scalability of such a server-based system depends on the number

of servers associated with each system function and their resources. At the other end of the spectrum are *peer-to-peer-based systems*. Here, each end user device acts as a peer, performing part of the presentation, simulation and storage functionality of the system. Together, all peers manage the MMVE in a fully distributed and typically self-organising way.

3 Current and future trends

Besides the basic issues, which have roots since the earliest virtual environment systems and are shared by all such systems, certain trends of today are creating new challenges for MMVEs. One trend is that the worlds are getting larger, both in the number of concurrent users (which currently ranges from typically thousands to tens of thousands), and the content within each world. The other trend is that virtual worlds are getting more dynamic due to the rise of *user generated content*. Users can have greater freedom and a larger impact in shaping how the world looks like. Although most MMOGs today still have teams of content creators responsible for content creation, virtual worlds such as Second Life allow complete user freedom to create the landscape, buildings, and items within the virtual world. Based on these observations, we can describe some current issues as follows:

Content delivery/streaming: As the world content gets larger (most of which is 3D content such as models and textures) into the range of many gigabytes and even terabytes, the current method of installing the full MMVE at the user's machine before entering the world may no longer be convenient or practical. Real-time content streaming thus may become the more viable approach.

Content creation: The generation of quality content is still a major bottleneck for MMVE development. Content creation often requires specific technical skills. In addition, the quality of the demanded content grows as hardware advances. For example, higher screen-resolutions require larger and more detailed models and textures. To solve this problem a number of techniques are required, based on automated content creation, user generated content, and the import of existing data, e.g., from geographic information systems. Without such techniques, content creation will stay a major bottleneck in making MMVEs larger or more usable by different user groups.

Interoperability: The most successful MMVEs today are all standalone applications, in the sense that they each require individually unique client program to run and use. The avatars and content created for one MMVE cannot be used in another, and often users are required to install a unique client for each MMVE accessed. This hinders the widespread usage of the various MMVEs, and reduces the potential cross-pollination among different MMVEs. For MMVEs to become truly widespread and universally useful, they may need to become more web-like, in the sense that a given world can be setup just like a website, and different MMVEs can be accessed with the same client program (i.e., a *universal client*). However, interoperability requires standardised communication protocols and content formats, which are not easy tasks given the diversity of MMVEs. Some current approaches include the Extensible 3D

(X3D) format for storing content (see Web3D Consortium, 2004), and the Second Life Grid Open Grid Protocol for communications (see Lentczner, 2008).

Density: Part of the reason why MMVEs can host thousands of concurrent users is that each user often only needs to be aware of a limited number of nearby users instead of everyone in the world. The filtering of messages according to each user's actual view, is key to keep the transmitted messages small. However, there are scenarios where one may indeed wish to see a larger number of other users, e.g., New Year Eve's countdown, or a popular sports event. Ensuring that the views of each user can still be maintained correctly, even when the density of nearby users increases, is one of the unresolved issues towards better realism.

Killer application: Although MMVEs have found a successful application in online games, for many non-gamers, MMVEs are still not a useful or necessary application. Many ideas and potential applications exist for a widely adopted MMVE, including education, training, shopping, socialising, or even politics. However, these are still in their early and often experimental stages, and are not used by the general public, e.g., the World Wide Web. At this time, we are still waiting to see an MMVE that could attract millions of concurrent users to participate in a single virtual world. Finding such an application thus is an important challenge.

4 Conclusion and outlook on the special issue

In summary, an MMVE provides a shared virtual world for at least many thousands of users across the globe to interact in immersive artificial environments. Challenges inherited from earlier multi-user virtual environments exist, while additional new challenges also arise due to the trends for larger and more dynamic worlds. In the following special issue, we collect some of the recent solutions researchers have proposed to address the above challenges.

The first challenge addressed in this special issue is the creation of a scalable distribution infrastructure to send data to clients requiring it – both small updates of the world state and large content files containing parts of the virtual world. Jean Botev, Alexander Höfeld, Hermann Schloss, Ingo Scholtes, Peter Sturm and Markus Esch present a Torrent-based approach for such an infrastructure in their paper 'The HyperVerse': concepts for a federated and Torrent-based '3D Web'.

On top of a distribution infrastructure, an entity management component is required. It should manage the entities comprising the virtual world, but the main question is how to partition the responsibility for managing a certain part of the virtual world to different management hosts. An approach based on the movement patterns of avatars in MMVE is proposed by Simon Rieche, Klaus Wehrle, Marc Fouquet, Heiko Niedermayer, Timo Teifel and Georg Carle in their paper 'Clustering players for load balancing in virtual worlds'.

Another challenge for MMVE developers is to achieve security in their systems. Due to the large number of users and the typically open user base, security is crucial for the success of any MMVE. Authentication as a basic security mechanism for MMVEs is presented by Arno Wacker, Gregor Schiele, Sebastian Schuster and Torben Weis in their paper 'Towards an authentication service for Peer-to-Peer based Massively Multiuser Virtual Environments'. Higher-level security is addressed in

'Scalable reputation management with trustworthy user selection for P2P MMOGs' by Guan-Yu Huang, Shun-Yun Hu and Jehn-Ruey Jiang. They propose a reputation management system to allow the detection of untrustworthy users.

We hope that this brief description can help those who are interested in MMVEs to be more familiar with the basic challenges and outlooks of the field, and that you will find the papers in this special issues interesting. Please visit the MMVE wiki page at http://mmve.wiki.sourceforge.net, if you would like to learn more.

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