Encyclopedia of Information Science and Technology

Second Edition

Mehdi Khosrow-Pour
Information Resources Management Association, USA

Volume VI
Mu-Q

INFORMATION SCIENCE REFERENCE
Hershey · New York

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Printed at: Yurchak Printing Inc.

Published in the United States of America by
Information Science Reference (an imprint of IGI Global)
701 E. Chocolate Avenue, Suite 200
Hershey PA 17033
Tel: 717-533-8845
Fax: 717-533-8661
E-mail: cust@igi-global.com
Web site: http://www.igi-global.com/reference

and in the United Kingdom by
Information Science Reference (an imprint of IGI Global)
3 Henrietta Street
Covent Garden
London WC2E 8LU
Tel: 44 20 7240 0856
Fax: 44 20 7379 0609
Web site: http://www.eurospanbookstore.com

Library of Congress Cataloging-in-Publication Data

Encyclopedia of information science and technology / Mehdi Khosrow-Pour, editor. -- 2nd ed.
p. cm.
Includes bibliographical references and index.
Summary: "This set of books represents a detailed compendium of authoritative, research-based entries that define the contemporary state of knowledge on technology"--Provided by publisher.
ISBN 978-1-60566-026-4 (hardcover) -- ISBN 978-1-60566-027-1 (ebook)
1. Information science--Encyclopedias. 2. Information technology--Encyclopedias. I. Khosrowpour, Mehdi, 1951-
Z1006.E566 2008
004'.03--dc22
2008029068

British Cataloguing in Publication Data
A Cataloguing in Publication record for this book is available from the British Library.

All work contributed to this encyclopedia set is original material. The views expressed in this encyclopedia set are those of the authors, but not necessarily of the publisher.

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Networked Virtual Environments

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INTRODUCTION

The inherent need of humans to communicate acted as the moving force for the formation, expansion and wide adoption of the Internet. The need for communication and collaboration from distance resulted in the evolution of the primitive services originally offered (i.e., e-mail) to advanced applications, which offer a high sense of realism to the user, forming a reality, the so-called virtual reality. Even though virtual environments were first introduced as stand alone applications, which could run on a single computer, the promising functionalities of this new form of representation and interaction as well as the familiarity of the users with it drew increased research interest. This fact resulted in virtual reality to be viewed as the solution for achieving communication and collaboration between scattered users, in various areas of interest, such as entertainment, learning, training, etc. This led to the creation of Networked Virtual Environments (NVEs). In particular, NVEs were first introduced in the 1980's and the first areas that exploited the newborn technology were military and entertainment applications. In particular, the U.S Department of Defense played an important role to the direction of applications, protocols and architectures for this promising technology. In the 1990's, where academic networks became a reality, NVEs drew increased academic research interest and a variety of applications and platforms were developed. In particular, the academic community has reinvented, extended, and documented what the Department of Defense has done. The evolution and the results extracted by research on this field were widely adopted from multiple areas of interest, with main representative the entertainment area.

Since 2000, where virtual reality technology, processing power of computers and the network were significantly improved, a wide variety of systems, protocols and applications were developed. In particular, the familiarization the end users with the Internet and the promising advantages and opportunities of Virtual Reality contributed to currently view NVEs as an effective tool for supporting communication and collaboration of scattered users. Currently, the application areas of NVEs have been widely expanded and their use can be found at military and industrial team training, collaborative design and engineering, multiplayer games (Zyda, 2005), mobile entertainment, virtual shopping malls, online tradeshows and conferences, remote customer support, distance learning and training, science, arts, industry, etc. Summarizing, NVEs nowadays tend to consist a powerful tool for communication and collaboration, with applications ranging from entertainment and teleshopping to engineering and medicine. To this direction, in the recent years important active research on this topic in both academic and industrial research is taking place.

BACKGROUND

NVE is a twofold term. Even though the "Virtual Environments" part prevails, the "networked" substance changes the meaning and nature of these environments. Regarding the Virtual Environment, it can be considered as a simulation generated by a computer, which can simulate either an imaginary or real world. Even though Virtual Environments can be two-dimensional, the term is mainly related to three-dimensional environments that aim at providing to the users a high sense of realism by incorporating realistic 3D graphics and stereo sound, to create an immersive experience. As far as it concerns the "networked" part of the term, this dimension is mainly related to the support of multiple concurrent users, scattered around the globe, even though NVEs can be single user applications. A definition provided by Singhal and Zyda (1999) states that "NVEs are software systems that can support multiple users, which can interact both with each other and with the environment in real time and aim at providing to the users a high-sense of realism by incorporating 3D graphics and multimedia."

The concept of a NVE is simple. Two or more users can view the Virtual Environment (VE) on their computer, having their own local copy of the virtual world. For achieving high-sense of realism and maintaining consistency, when a user performs actions on one computer, these actions are propagated through the network to other participating computers for keeping all copies of the VE synchronized. The participants constitute active parts of the VE, usually represented by human-like entities, called avatars for enhancing the awareness (Joslin, Pandzic & Thalmann, 2003).

As mentioned earleir, the network constitutes the core of NVEs. However, NVEs can be further categorized by their architectural model or the nature, in terms of the kind of application they plan to support (Macedonia, 1997). In particular, regarding the architectural model, the most popular category of NVEs are the Distributed Virtual Environments (DVEs), where active parts of the virtual environment are scattered to different computers, which are connected through the network. Accordingly, in respect to the nature of these environments, one of the major categories are the Collaborative Virtual Environments (CVEs), where the users have the ability to meet and interact with others, with agents and the objects of the virtual environment.

MAIN ISSUES AND CONCEPTS IN NVES

A NVE constitutes a computer system, which generates virtual worlds, where the users can interact both with the system and the other connected users in real time. The users are connected to the Internet and working on different computers, access the same virtual scene. The simulation of the virtual scenes is realized through distributed and heterogeneous computational resources. The evolution of the software applications and services in combination to the melioration of the network allows for the development of networked applications, which are characterized by the enhancement and combination of many advanced features. For NVEs in particular, where the achievement of high realism constitutes a key concept, the realistic and detailed representation of the provided information is of high importance. Therefore, the potentialities that technology presents in combination to the increased needs of the users result in NVEs to adopt rich representation for the information in terms of graphics and media.

Despite the fairly simple concept, the design of NVE systems involves a complex interaction of several domains of Computer Science. In particular the interacting domains are the following: (a) networking, which is related to the transmission of various types of data with different requirements in terms of latency, bitrate, and so forth, (b) simulation, which is related to the virtual environment and involves visual database management and rendering techniques with real time optimizations, (c) human-computer interaction, which is related to the support of various types of devices, (d) virtual human simulation, which is related to the avatar's realistic representation in terms of facial expressions, motions, and so forth, and (e) artificial intelligence involving decision making processes and autonomous behaviors (Joslin et al., 2003).

This section will present the basic issues related to NVEs, in terms of the basic features they need to support, the components necessary, in terms of the hardware needed for their operation and interaction with the users, the most common architectures adopted for supporting such environments, the technologies and protocols for their development as well as the issues and factors that should be taken into account for assuring a good performance.

Basic Characteristics

As mentioned above, NVEs can represent either a real or imaginary world. Thus, the structure, the space, the objects and the functionalities provided in such an environment may significantly vary in respect to the concept they aim to support. However, for achieving a high sense of realism, NVEs are characterized by some common features. In particular, these environments should provide: (a) a shared sense of space, in terms of creating the illusion to the users that they are being located in the same place, (b) a shared sense of presence, which is mainly related to the virtual representation of the users that is commonly realized through human-like personas called avatars as well as to the visibility of others participants entering or leaving the environment, (c) a shared sense of time, in terms of being able to see other participants' actions when they occur, (d) a way to communicate, which can be achieved through gestures, typed text and voice and finally (e) a way to share, in terms of being able to interact realistically not only with other participants but also with the virtual environment itself (Singhal & Zyda, 1999). The support of the above-mentioned characteristics is critical for the successful simulation of reality and vital for the effective communication and collaboration of the participating users.

Basic Components

In terms of the hardware needed for NVEs, four components are found necessary for the correct and successful operation of these environments. In particular the components needed are: (a) graphics engines and displays, which constitute the cornerstone of the user interface and the users' "window" to the environment, (b) communication and control devices (e.g., keyboard, mouse, joystick, dataglove, head mounted display, motion detectors in full-body immersive environments), which allow and support the manipulation of the objects of the environment as well as the navigation and interaction of the user with the environment, (c) processing systems for computing and determining the transmission of the events that take place within a virtual environment and last but not least (d) data network for the actual communication, transmission of information and sharing of data. The components work together for achieving and maintaining the sense of realism among the scattered users.

Architectures

From a more technical point of view, the architectures that support these types of software systems usually fall into one of the following cases: (a) client-server architectures, where the clients communicate their changes to one or more servers and these servers, in turn, are responsible for the redistribution of the received information to all connected clients and (b) peer-to-peer architectures, where the clients communicate directly their modifications and updates of the world to all connected clients (McGregor, Kapolka, Zyda & Brutzman, 2003). The case of the client-server model is the most simple but it is cannot support high scalability as there is a central point of failure, the server. As far as it concerns the peer-to-peer model the scalability is restricted by the network. It should be mentioned that hybrid solutions can be adopted, in regard to the specific needs and the type of the application that each system aims to support. However, there are hybrid architectures, which adopt the simple client-server model with peer-to-peer communication among groups of servers or with server hierarchies, where certain servers act as clients to others. In addition, the client-server and peer-to-peer structures can be integrated into peer-server architectures, where some data packets are transmitted through certain nodes using peer-to-peer while other data are transmitted though a server.

Technologies and Protocols

This subsection presents some of the commonly used technologies for the creation of 3D content as well as the protocols available for the support of the networking feature of the NVEs.

3D Internet Technologies for NVEs

There is a large number of technologies for the development of 3D content, each of which provides certain functionality. Some of the most know 3D technologies are (Diehl, 2001): VRML, Extensible 3D (X3D) and Java3D API. These technologies vary on the way an object/model is represented, on their ability to support animations, whether they provide a programming interface, whether they support streaming, and so forth. It becomes clear that the selection of an appropriate technology depends on the needs and requirements of the application developed. The main standard in this area is X3D, which is the open standard for Web-delivered three-dimensional graphics. It specifies a declarative geometry definition language, a run-time engine, and an application programming interface (API) that provide an interactive, animated, real-time environment for 3D graphics (Daly & Brutzman, 2007). As described in Bouras, Panagopoulos, and Tsiatsos (2005) there are some X3D enabled NVEs platforms as well as possible solutions for migrating from a VRML based multiuser platform to X3D available.

Protocols

The protocols used for the support of NVEs depend mainly on the networking solution that each system adopts. For NVEs the protocols most commonly used are the following: at the network layer the Internet Protocol (IP) and at the Transport Layer the Transmission Control Protocol (TCP), the User Datagram Protocol (UDP) and the Multicast IP protocol. It should also be mentioned that for Distributed Virtual Environments, which constitute a subset of NVEs there are additional protocols, which meet the specific needs of this type of applications and are the following: the Distributed Interactive Simulation (DIS) protocol, the Distributed Worlds Transfer and Communication Protocol (DWTP) (Broll, 1997), the Multi-User 3D Protocol (Mu3D) (Galli & Luo, 2000) and the Virtual Reality Transfer Protocol (VRTP) (Brutzman, Zyda, Watsen & Macedonia, 1997). As stated in (Diehl, 2001) there is no protocol able to serve all types of applications equally. Thus, based on the type and requirements of the developed application the appropriate protocol should be adopted for optimized performance and results.

Design and Development Challenges

The complexity of NVEs is mainly related to the need and desire to achieve a high-sense of realism. This fact results in applications that need to include multiple traditional software types, rich graphics, and compatibility with other applications. The networked nature of these environments is an additional factor that affects their complexity, in terms both of the development and deployment. In particular, NVE development is a difficult balancing act of trade-offs, as there are a number of factors that should be taken into account for optimizing the networking performance of the system (Diehl, 2001). These factors are: (a) the network bandwidth, which constitutes a limited resource and therefore the allocation of its capacity should be carefully determined, (b) heterogeneity, which is related to the quality of service that users with diverse equipment (e.g., processing system, network connection, graphic resolution) can achieve, (c) distributed interaction, which is related to the fact that the system must provide each user with the illusion that the entire environment is located on the local machine and that the actions of the users have a direct and immediate impact on the environment, (d) the real-time system design and resource management, which defines the process and thread architecture of the application, (e) the failure management that concerns the reaction of the system in a possible failure and its impact on the users' view, (f) the scalability, which is related to the need for supporting a larger number of concurrent users and finally (g) the deployment and configuration, in terms of how the software will be accessible by the end users. It is very difficult to determine a formula that can satisfy all the aforementioned factors and resolve the limitations that each of them introduces, as the dependency among them is strong and improving one's behavior can affect other component's behavior as well (Singhal & Zyda, 1999). Therefore, based on the specific type of the application as well as its target group the developers need to specify their priorities for the design and development.

FUTURE TRENDS

As stated previously, NVEs are complex systems, which incorporate a number of applications and different technologies. In particular, the NVEs currently developed are prototyping the information infrastructure of the next century in terms of advanced networking, virtual reality, high performance computing, data mining, and human/computer interactions. Thus, there is a wide range of areas that can be further developed and improved for the optimization of these environments and their wider adaptation. Based on the fact that NVEs allow multiple participants to collaborate using high-speed networks connecting heterogeneous computing resources and large data stores, NVEs could further extend the human/computer paradigm so as to include human/computer/human collaborations. Another direction that draws increased interest for NVEs is the ability to efficiently support large-scale applications. The term "large-scale" refers both to the data size (in terms of virtual space and graphics) as well as to the concurrent number of users that can participate (Bouras, Giannaka, Panagopoulos & Tsiatsos, 2006). To this direction, research has already begun producing techniques and algorithms for achieving this challenging task. Moreover, the need for an advanced sense of realism seems to emerge, especially where the relationship between the virtual world and the everyday physical world is concerned (Benford, Greenhalgh Rodden & Pycock, 2001) while ubiquitous, mobile, and wearable computing promises to make access to digital information universal and continual. Finally, many ideas and technological solutions could be adopted by 3D games technology in order to use these environments to support other applications. As Zyda (2007) said, "the same technology that makes interactive 3D games so entertaining in the physical action domain is just as effective in education, training, and other more serious applications."

CONCLUSION

In this chapter we presented the basic issues of NVEs. The areas covered were: the basic characteristic and components of NVEs, the architectures, technologies and protocols available for their development as well as some design and development issues that should be taken into account when designing and developing a NVE. It is obvious that, as technological challenges are overcome, NVE systems tend to become more and more powerful communication and collaboration tools on various fields of interest.

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KEY TERMS

CVE: Collaborative Virtual Environment is an extension of a NVE which aims at a collaborative task. CVEs aim to provide an integrated, explicit and persistent context for cooperation that combines both the participants and their information into a common display space. These objectives create the potential to support a broad range of cooperative applications such as training.

DIS: Distributed Interactive Simulation is an open standard for conducting real-time platform-level wargaming across multiple host computers and is used worldwide especially by military organizations but also by other agencies such as those involved in space exploration and medicine.

DVE: Distributed Virtual Environment is an NVE where active parts of the virtual environment are scattered to different computers, which are connected through the network.

HLA: High Level Architecture is a general purpose architecture for distributed computer simulation systems. Using HLA, computer simulations can communicate to other computer simulations regardless of the computing platforms.

Java 3D API: The Java 3D API is a hierarchy of Java classes which serve as the interface to a sophisticated three-dimensional graphics and sound rendering system. Java 3D provides high-level constructs to create and manipulate 3D geometry, and to build the structures used to render that geometry.

NVE: Networked Virtual Environment is a virtual environment that allows a group of geographically separated users to interact in real time

X3D: Extensible 3D is the open standard for Web-delivered 3D graphics. It specifies a declarative geometry definition language, a run-time engine, and an application programming interface that provide an interactive, animated, real-time environment for 3D graphics.

VE: Virtual Environment is a computer-generated simulation with which the user can interact in such a way that he receives real time feedback aiming to provide its users with a sense of realism.

VR: Virtual reality is a technology which allows a user to interact with a computer-simulated environment.

VRML: Virtual Reality Modeling Language is a standard file format for representing 3D interactive vector graphics, designed particularly with the World Wide Web in mind.