Desktop Virtual Reality Applications for Training Personnel of Small Businesses

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Abstract

Small and medium-sized businesses (SMBs) in most world economies suffer from a series of intense economic pressures from local, regional and international markets. Although these problems are microeconomic to the small and medium-sized business, they are directly related to macro economic factors, particularly in the case of labor. One of the main pressures small and medium-sized businesses suffer from is the lack of worker technical skills. Past research has consistently shown that virtual reality (VR) can be effective for supporting competency-based training skills. The objective of this chapter is to provide an overview on how virtual reality can be used to support technical training in SMBs, including the use of Second Life and DIVE VR platforms. This chapter describes a desktop VR Application for training car mechanics from a small business and highlights advantages and challenges of desktop virtual reality for technical training. Finally, future trends related to the use of VR in training are discussed.

Keywords: Virtual reality, Small and medium-sized businesses, Training, Skills, Semi-immersive, Desktop.

Introduction

Small and medium-sized businesses, or SMBs, comprise more than 90% of the firms operating in most world economies. These businesses play a critical role in the economic activity of their respective countries in almost all productive sectors and contribute to the majority of employment and the gross domestic product (GDP). As the U.S. Census Bureau points out (U.S. Census, 2007), small and medium-sized businesses have fewer than 100 and 500 employees, respectively. Similarly, the European Union establishes that small businesses have fewer than 50 employees, and medium businesses have no more than 250 employees (European Commission, 2005).

However, SMBs worldwide suffer intense economic pressures from local markets as well as competition among regional and global competitors. In addition, a number of problems associated with a lack of skills affect the productivity and ultimate survival of SMBs. According to Hamburg and Engert (2007), SMB employees often lack necessary skills to remain competitive in national and international markets. Moreover, SMBs need to develop core competencies to succeed, such as technical topics, including information technology (IT) competencies (Mascarenhas et al. 1998; Tapias Garcia, 2005).

Small businesses need to define skills and core competencies, since they are a basis for marketing, and for making operational decisions. If a business plans to grow, it needs to develop existing core competencies and expand them. If a SMB does something very well and remains focused on it by means of adequate training, it will have a competitive advantage and tend to become a leader in the specific business field (Srivastava, 2005). There is no question that the development of core competencies can be achieved with the support of technology.

Past research shows that computer and Internet-based specialized instruction (e-learning) is an effective way to deliver training courses. Recently, technologies like virtual reality and 3D graphical models displayed on Web pages have been effectively researched and employed for technical training (Gerbaud & Arnaldi, 2008). Virtual reality, or VR (Burdea & Coiffet, 2004; Sherman & Craig, 2003), today, is one of the new frontiers in training and education, both of which extend to the workplace. Some of the advantages of using virtual reality in training and education include first-person experience, active trainee participation in the learning process, multimodal learning (the use of multiple human senses to perceive information), ease of communication between trainees and instructors by decreasing anxiety, lowering of social barriers in a collaborative virtual environment (Youngblut, 1998), as well as enhancing trainee perception and analysis of 3D graphical models and other types of technical information (Dede et al., 1996; Roussos et al., 1997), among others (Cao et al. 2008).

The objective of this chapter is to provide an overview of desktop virtual reality and how it can be used to support technical training in SMBs. This chapter also highlights advantages and challenges of virtual reality for training. In addition, two important, economical and widely used programs for developing and displaying desktop virtual environments are also analyzed for their potential use in training.

Section **Background** describes an overview of technology applied for training personnel in SMBs.

Section **Virtual Reality Technology** outlines a general description of research and applications carried out with virtual reality (and what it is not) and its classifications.

Section **Second Life** refers to a description of this virtual environment and current Second Life applications for education and training.

Section **DIVE and Other VR Platforms** covers a general description of Distributed Interactive Virtual Environment (DIVE), an open source program for developing collaborative virtual environments.

Section **A VR Application for Training Car Mechanics** describes a virtual reality application, and results of its usability study, to train car mechanics needing to learn about an automobile part in a small car repair garage.

Section **A Comparison of Second Life and DIVE** provides a comparative analysis of the technical advantages and challenges of Second Life and DIVE.

Section **Future Trends** offers a vision of future research and virtual reality applications applied to training, and what needs to be explored with regards to training and augmented reality.

Section **Conclusion** focuses on the applications of open source software and desktop virtual reality hardware to SMBs for training.

Background

How to best teach the knowledge, skills and competencies necessary for persons to join the workforce and productively contribute to the production of wealth of businesses is the subject of much debate. One general consensus among companies, however, is that training personnel should be carried out quickly, efficiently and inexpensively. The two most common strategies to train personnel are before they enter the workplace, an approach commonly used to train first-time employees, or on-the-job training, for employees who require honing their skills or learning new competencies. These two paradigms of training personnel are becoming more and more relevant as the present worldwide economic crisis forces an almost unprecedented percentage of the workforce to seek new employment opportunities and acquire new skills and competencies and obliges companies to modernize their systems of production and reconsider models of competitiveness. Training personnel is particularly important for small and medium businesses (SMBs) who chronically suffer from a fluid workforce that often does not possess the skills necessary to optimally contribute to the business (Mullins et al., 2007).

The U.S. Small Business Administration (SBA, 2008) currently classifies a business or firm with less than 500 employees as small. The relevance of this chapter is that even though the contributions of SMBs are extremely important, their special concerns are rarely studied in academic and professional journals (Schleich et al., 1990). This is particularly surprising when the importance of SMBs is considered in the context of overall economic welfare. As many as five of every six pay checks in America come from firms with less than 1000 employees and close to 70% of these people work in companies with fewer than 100 employees (Carnevale, 1991).

In a longitudinal study, The United States Department of Labor (USDL, 2008) interviewed 9,964 men and women in 1979 when they were between the ages of 14 and 22. This study, which covers more than a quarter century, interviewed these respondents biannually. The most recent results reported in June, 2008, reveal the following:

- Individuals born between 1957 and 1964 held an average of 11 jobs between the ages of 18 and 42.
- As the baby boomers became older (38-42), the number of jobs they held during this four-year period average almost 2, a very significant number.
- In the 38-42 year-old age group, 31% left their jobs in less than a year and 65% in fewer than 5 years.
- Inflation-adjusted earnings increased most rapidly (7%) for younger workers between 18 and 22 years of age primarily because they worked at entry-level jobs. Earning growth slowed to 3.1% and 1.4% in the 33 to 37-year olds and 38 to 42 year-olds, respectively.

These statistics lead to some very significant conclusions:

- Mobility is great among all age groups, although it is greatest among younger workers because salary differences between entry level or minimum salary jobs and more stable long-term jobs provides sufficient financial incentives to improve earnings.

- As workers become older, they tend to become more stable enjoy smaller salary increases as they reach the top of their pay schedules. However, these adults still change jobs at a very significant pace.

- The fluidity of the workforce requires businesses have well-established strategies to accommodate the constant entrance and exit of its workforce.

- Small and Medium businesses are no exception to these statistics. In fact, because of the small number of employees working for them, they are more susceptible to production problems due to labor considerations.

In the last quarter century of the 20th century, computer technology became more widespread in business and industry. However, due to the costs and lack of know how, much of the early computer technology did not “tickle down” to SMBs. The sometimes prohibitive costs of hardware, software, licences, and training made it difficult for small businesses to enjoy the benefits of computer technology. Although the use of information technology (IT) is growing in SMBs, its use still pales in comparison with IT use in large companies, depending, in part, on the location, size, and nature of the business (Alexander, 1993).

Small and middle sized businesses are largely reluctant to accept new technologies because of: “internal uncertainty, bad experience with previous implementations, lack of honest, reliable partners / media consultants, inadequate hardware infrastructure and, of course, price.” For these reasons, particularly in Europe, there is always a considerable delay before companies take “the decision” to use newly available technologies. On average, it takes about 3 years to reach any next particular level in state-of-the-art technologies. The main task is, in a sense, to "cut the coat to fit the cloth," which in this particular case means adapting (online) applications to the equipment and knowledge level of a “normal,” technically untrained user who probably does not even possess an up-to-date internet browser. It is cost effectiveness and the overall benefit to a company which ultimately determines how quickly or whether, if at all, a new technology will be incorporated. The challenge over the next few years will be how to deliver affordable, intuitive and easy computer and communications solutions to the workplace (Wierzbicki & Margolf, 2002).

Prashant et al. (1999) discuss two major variables concerning how IT is accepted in SMBs, including the following:

- Business factors:

  Type of business: Retailers and wholesalers appear to be the most “sophisticated” users and there appears to be significant differences between the manufacturing and service sectors.

  Business size: Investment in technologies is less “risky” in larger businesses.

  Profitability: How much the system costs and how much will it maximize profits.

  Location: How close the business is to competent technical support.

- Owner characteristics:

  Age: Older users tend to be less knowledgeable and more distrustful of technology.

  Race: There appear to be differences in how technology is perceived due to socioeconomic and educational considerations

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  Education: Persons with university degrees graduate with greater computer skills and tend to accept IT much quicker than homologues who have not acquired basic computer competencies.

  Computing skills: The greater the owner’s computer skills, the more like he/she is likely to introduce computers to the workforce.

The concept of training, particularly in the case of SMBs, has greatly evolved over the last 30 years. The first training courses were knowledge based, stimulus-response programs because of the limited processing power and limitations related to programming languages. However, since the 1990’s considerable attention has been given to virtual reality (VR), primarily because it can provide “real-life” experiences in simulators that integrally engages its users (Vince, 2004). According to Rogers’ (1969) experiential learning theory, learning should be significant and best takes place when the subject matter is relevant to the personal interests and needs of the student, the learning experience is non-threatening, and self initiated learning is the learning that tends to be more permanent.

According to Knowles' (1975, 1984) Theory of Andragogy, adults need to be actively involved the planning and evaluation of their instruction. This suggests that IT experts need to collaborate with the actual workers to design learning environments to suit their needs. Furthermore, Knowles maintains that instruction should be task-oriented and learning activities need to be contextualized according to the task that is to be performed. Lastly, Knowles maintains that adults are most interested in learning what is immediately relevant to the job and that adult learning needs to be centered more on problem solving than acquiring knowledge.

Finally, according to Cross (1981), who echoes the views of Knowles (1975, 1984) and Rogers (1969), adult learning programs need to capitalize on the actual experiences of the learner, should move from simple to more complex tasks and skills, adult learning programs should adapt to the cognitive differences of adults and that adults should be given as much choice as possible in how learning programs are organized.

Immersive VR technology has excellent potential to contribute to adult learning and training in the workplace (Bricken & Byrne, 1992). However, fully immersive VR technology still remains far too expensive for small and medium size businesses and is generally used in high-end simulators for government (NASA, military and the airline industry) or educational (language learning, medicine, engineering, physics, and chemistry). Fully immersing learners is motivating and encourages them to participate as persons interacting in a space that can suspend physical and temporal restrictions that would otherwise be imposed on them. According to (Yahava et al., 2004), a person's willingness to either live a real-life situation or an environment that supersedes the laws of physics, provides a presence that significantly contributes to perseverance.

Virtual Reality Technology

Virtual reality (VR) is a computer-based technology capable of generating a 3D space (also called virtual environment), has three main characteristics: It is multi-sensorial, interactive and integrally engages its users with the psychological effect of immersion (Burdea & Coiffet, 2004;). However, virtual reality must comply with the three characteristics, otherwise it is just a 3D graphical simulation shown on a computer screen (Sherman & Craig, 2003).

VR is classified according to the level of immersion (the subjective perception of being present in a virtual environment) it provides. Semi-immersive (or desktop) VR usually employs a typical desktop or laptop computer and its monitor to watch the virtual environment and interact with it, using either a conventional mouse or keyboard, and listening to sounds from the virtual environment using a couple of speakers or headphones. In a more sophisticated desktop VR, however, the user may also wear 3D glasses (such as anaglyphs or shutter glasses) to watch the 3D environment in stereo using stereoscopic projections. These types of projections may support 3D model visualizations and enhance immersion, although non-stereoscopic visualization provides a certain degree of effective immersion. Figure 1 shows a basic desktop VR system configuration without the 3D glasses.

Figure 1. A basic desktop (semi-immersive) VR system.

In fully-immersive VR environments, though, users watch the virtual environment that is projected in a VR helmet, manipulates virtual objects and navigates through the virtual environment using special data gloves with sensors, while listening to sounds through high fidelity headphones (Burdea & Coiffet, 2004). Although immersive VR offers a greater immersion effect than the desktop VR, both are effective in educational settings. The difference is that the equipment used for fully-immersive VR simulators is very expensive, complex to maintain, and requires specially trained professionals to employ and adapt them in educational or training settings. For these reasons, fully-immersive equipment cannot be bought, employed and maintained by many SMBs. Figure 2 depicts a fully-immersive VR system.

Figure 2. A fully-immersive virtual reality system.

Both desktop and fully-immersive virtual reality has been used by large industries to train their personnel.

In an early study, Adams (1996) describes an informal study carried out by a large pager maker and a consultancy business from the US about training employees to supervise a pager production line. A production line was recreated in a desktop and effects of the fully-immersive virtual environment were reported. Results showed that trainees who used VR committed fewer errors and understood the process faster than personnel who used real equipment for their training. Recent VR applications include employee training to operate mining equipment (van Wick and de Villiers, 2008) and the widespread use of virtual reality simulators to train medical personnel (Alverson et al., 2005), among others.

A late nineties report on virtual reality applications in education (Youngblut, 1998) highlighted that desktop virtual reality can provide cost-effective and adequate technological support for education and training. The same report pointed out (almost a decade ago) that desktop VR is a mature technology that can make use of the latest personal computers. In addition, it is likely that according to current unstable world economies, the development of fully-immersive virtual reality applications for training will decrease, at least for SMBs that have greater difficulty acquiring such equipment. There is relatively little literature on desktop VR applied to SMBs, despite how it can complement or enhance technical training.

A number of research institutions around the world have developed and tested networked collaborative virtual environments for education and training since the early nineties. Collaborative VR is a shared virtual environment using a local network or the Internet, where its users interact to work, learn, train, and perform other activities together (Benford et al., 2001). Until recently, however, there was insufficient computer and network power or adequate coding-decoding algorithms (codecs) to carry out smooth communications and immersion of participants in CVREs. Consequently, the result has been a trade-off between realism and speed (due to latency), as well as limited modality interactions that have focused almost exclusively on the exchange of visual and auditory information (Gutierrez, Vexo & Thalmann, 2004; Chan & Lau, 2004).

Second Life

Second Life (SL) is an online virtual world where millions of Internet users are registered and presently contribute by developing and uploading graphical objects, buildings, etc. Its users can interact as virtual personifications called avatars, and they can communicate using text messages and their voice, using voice over IP (VoIP). Its web page is http://secondlife.com. In general, users can personalize Second Life graphics and many of its features. For example, users can change their avatar's garment to use "designer" clothes, as well as trade and sell goods and services using Second Life's own money, called Linden Dollars. The ability to personalize the Second Life environment is compelling and fun. There are two versions of Second Life, one for adults and one for users under 18 years of age, called Teen Second Life. An entire SL virtual environment is called a "metaverse." The metaverse contains "islands" that can be purchased and owned for a fee from Linden Labs (the business that created Second Life) or from other SL residents. Once users purchase an island, they can opt for using their islands for whatever purpose they desire. Second Life applications are mainly for entertainment, but they have potential educational potential. Education and general training are not opposed to providing fun and entertainment. For instance, in foreign language learning, fun and humor are ways to lower the “Affective Filter.” By lowering the affective filter to learning, one also lowers anxiety and other negative feelings towards a learning experience (Krashen, 1982, 1988). There are already a number of educational islands that are owned by universities and private firms around the world, where courses are being taught. In addition, some educational institutions provide virtual facilities to their students, such as virtual classrooms, laboratories, and libraries (Gollub, 2007). Second Life also contains virtual museums that can be used in educational activities, too.

Consistent with Stephen Krashen's ((Krashen, 1982, 1988) hypothesis about the affective filter and language learning, there are presently important educational institutions offering second language learning (LL2) classes in Second Life, such as the internationally recognized Instituto Cervantes of Spain. This institution also has a virtual library containing books in Spanish, as well as Spanish memorabilia and a virtual expo hall. Its website is: http://secondlife.cervantes.es/ (in Spanish). Moreover, recent research points out that health institutions have studied Second Life for training personnel.

However, there are few reported cases in the literature about using SL specifically for training. For example, according to Gronstedt (2007), large IT companies such as IBM, Intel, Dell, and others, are investing in the development of virtual islands, offering courses and technical training in Second Life for their employees, although reported studies about SL applications in training still need to be published. Some people involved in these companies helped create SL islands and predictions are that the number of users will grow steadily, especially users from emerging economies like Brazil, India, and China (Gronstedt, 2007).

It appears that one secondary benefit of using collaborative VR like Second Life is to help reduce fuel costs of students and teachers in distance education programs, as they can avoid commuting to and from school every day (Theil, 2008).Other important benefits include quality of life concerns of people who can train at home or at more convenient hours and at lower costs for the SMBs, who can train employees to perform specific tasks at home, thus reducing training time and the risk of damaging actual equipment or risking harm to their employees.

Nevertheless, in order to run smoothly, Second Life requires a considerable amount of computer resources, such as an efficient video graphics card, a large RAM memory, and a reliable Internet connection with large bandwidth, from 1.544 to 6 Mbps. According to SL´s web page, it needs a cable or DSL connection for accessing the Internet, and warns that "Second Life is not compatible with dial-up internet, satellite internet, and some wireless internet services." These requirements are strict, since we have collaboratively tested SL with very modest success on a local network connected to the Internet through fiber optics and with about 500kbps at the time of testing. It was not possible to run SL with slower Internet connections or with computers with less than 1Gb video RAM. A possible way to improve access to Second Life metaverse is to arrange a guaranteed Service Level Agreement (SLA) with the Internet service provider, or to increase the bandwidth connection, although these can be costly solutions for smaller businesses.

Although the network requirements of Second Life to efficiently run over Internet connection is with cable or DSL, we believe that SL may run with IEEE 802.11g wireless networks for a small group of users accessing the network at the same time. However, we recommend using SL over WiMAX (Worldwide Interoperability for Microwave Access) technology, already available in some cities around the world. WiMAX is a recently created wireless communication medium to provide up to 72 Mbit/s symmetric broadband speed, suitable for multimedia and other types of data, based on the broadband wireless access IEEE 802.16 standard (Kumar, 2008).

An important problem with collaborative VR environments like Second Life is that users get frustrated when the local network or the Internet access is slow, greatly affecting VE visualization, sound perception and user communication in the shared virtual environment due to increased latency. This also has been noted in other collaborative VR studies (Fraser et al., 2000). In addition, increased latency will almost certainly hinder user performance, affecting completion of training objectives in future VR applications. One of the main causes of slow collaborative VE access is network delay that is caused by the way VR information (in the form of packets) is delivered onto a local network or over the Internet, and how that information is processed at each computer connected to that network (Gutwin et al., 2004). Network delay also produces latency in collaborative virtual environments, which can be defined as the period of time required to update and display the shared virtual environment for all the users. Network delay can greatly affect group interaction and the sense of immersion the virtual environment produces (Burdea & Coiffet, 2004).

Figure 3 shows one engineering student (from a group of five) collaborating in Second Life to test technical aspects in an informal usability exercise that helped us measure the network speed and other network characteristics. The desktop computers they used have one Mb of RAM, with video cards of 128 Mb of graphics memory. The used local network is composed of a 100 Mbps switch with approx. 500 kbps of Internet connection.

Figure 3. A student testing the usability of Second Life.

Although registering in Second Life is free at the moment, its users have to pay fees for entering and using some SL islands. It is worth trying a third-party Second Life viewer (client) called Onrez (http://viewer.onrez.com/). Onrez runs somewhat faster than the viewer developed by Linden Labs. There are other third-party companies and research groups that have developed Second Life viewers, available from: http://wiki.secondlife.com/wiki/Alternate_viewers.

DIVE and other VR Platforms

There are alternatives to Second Life that may run with fewer computing requirements, and as stand-alone VE, such as DIVE (Distributed Interactive Virtual Environment), an open source program for collaborative VR developed by the Swedish Institute of Computer Science (Carlsson & Hagsan, 1993). Its web page is: http://www.sics.se/dive. Steed and Frecon (2005) describe DIVE as a peer-to-peer collaborative virtual environment that allows the virtual environment sharing between various participants in real time, where they can effectively communicate among themselves through voice-over IP (VoIP), gestures, and text messaging. Similar to Second Life, DIVE allows collision detection programming of virtual objects to enhance VE realism. Moreover, Steed and Frecon (2005) point out that DIVE does not intended to produce photorealistic environments representing the real world, because it has been found that well-programmed virtual objects and avatar behaviors are more important than their photorealistic appearance to obtain realistic and convincing virtual environments, thus enhancing immersion (Freeman et al., 2003). DIVE also provides realistic spatialized (3D) sound capability. DIVE has been used mainly for research, and there have been a number of studies about using desktop VR and DIVE for education and training (Garcia-Ruiz et al., 2008; Garcia-Ruiz & Alvarez-Cardenas, 2005; Cervantes-Medina, 2004).

Other open source programs include VR Juggler, created by Iowa State University's Virtual Reality Applications Center in the United States. An alternative to virtual environments for training is VRML, which stands for Virtual Reality Modeling Language, one of the first standardized languages for using 3D virtual environments on the Internet. There are a number of open source and commercial VRML navigators and 3D graphics modelers (the programs for making virtual environments and its contents) that have been effectively used for training stand-alone users, because VRML itself does not work collaboratively, although a new version of VRML, called X3D, will have this capability. For a description of X3D see: http://www.web3d.org/x3d/. Table 1 shows a partial and non-exhaustive list of the aforementioned VR programs that allow collaborative applications.

It is also possible to use programming libraries, application programming interfaces (APIs), and graphics engines to create video games, commercially available or as open source. A Wikipedia page shows a comprehensive list these engines: http://en.wikipedia.org/wiki/List_of_game_engines. A 3D API for Java language called Java3D has been successfully used over the past ten years for creating virtual environments, mainly for research applications.

Program name	**URL**	**¿Open source or commercial?**
Distributed Interactive Virtual Environment (DIVE)	http://www.sics.se/dive	Open source
VR Juggler	http://www.vrjuggler.org	Open source
Second Life	http://secondlife.com	Open source/commercial
X3D programming language viewers/ authoring tools	http://www.web3d.org/x3d/content/examples/X3dResources.html#Applications	Open source
Avango	http://www.avango.org	Open source
World2World	http://www.sense8.com	Commercial
Flatland	Http://www.flatland.com	?

Table 1. A list of programs used for collaborative VR.

Past research has found that if educational technology has a high degree of usability, it will support learning and training more effectively, and will improve student motivation about its use (Zaharias, 2004; Zaharias, 2006; MacFarlane et al., 2005). The International Organization for Standardization (ISO) defines usability as “The extent to which a product can be used by specified users to achieve specified goals with effectiveness, efficiency, and satisfaction in a specified context of use” (ISO 9241-11, 1998). In addition, researchers have studied virtual environment usability for more that a decade, demonstrating that usable virtual environments lead to better user acceptance and user interactions in a virtual environment (Kaur et al., 1998). For instance, virtual reality medical simulators that have been improved in their usability and positively support skill transfer in medical training (Alverson et al., 2005). Van Wyck and de Villiers (2008) also point out that it is important to take into account the context of use when designing usable virtual environments for training, especially if personnel will be trained to operate in hazardous areas such as mining.

A Desktop VR Application for Training Car Mechanics

We devised a virtual reality environment with the objective to support training mechanics in assembling a car distributor (Garcia-Ruiz & Alvarez-Cardenas, 2005). For some mechanics, this engine part is often difficult to check and assemble, and printed instructions are not clear enough for them. To see how useful DIVE or SL could be for training mechanics, we carried out a preliminary usability test of the virtual environment with the virtual distributor. DIVE was used because it is easy to handle in a basic laptop computer, which requires less bandwidth. However, the results of this study are valid for Second Life because it can produce exactly the same virtual object that was used in this study.

Materials

We used Distributed Interactive Virtual Environments (DIVE) to show the virtual environment, and an AC3D graphics modeller to develop the 3D model of the distributor. Its web page is: http://www.inivis.com/. The 3D models created with the latest AC3D version can be exported to DIVE format. Figure 4 shows the engine distributor used as a reference to create a 3d model. To the right is a representation of the virtual model used in the study. The virtual environment development was part of an engineering thesis project from our University (Esqueda-Machiche, 2005).

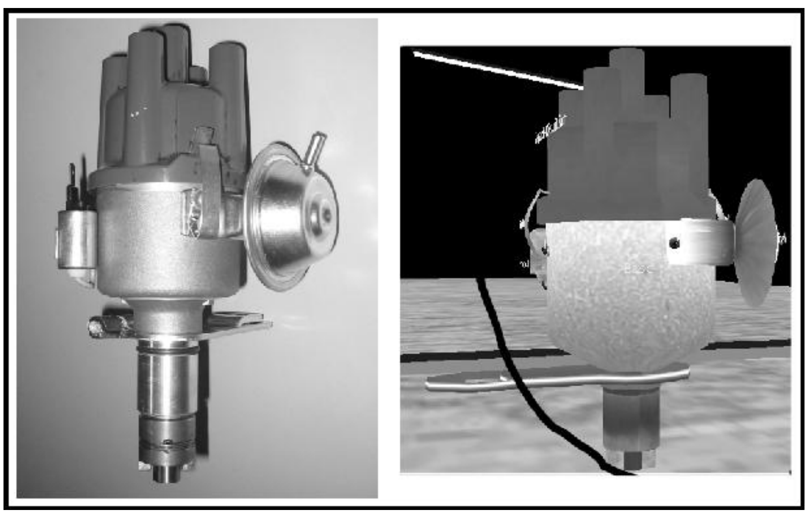

Figure 4. A photo of the original car engine distributor and the created 3D model.

The virtual environment was developed following Fencott´s (2005) methodology, which is intended to obtain a usable virtual reality interface. This methodology is also suitable for integrating multimedia elements, such as 3D graphics, sounds, and images. The design objective was to develop the virtual environment and to set up DIVE navigation controls as simple as possible. In order to improve the VE, there various prototypes of the virtual environment were developed before the usability test was carried out. The various prototypes were used to make correction to the 3D model and the VE. The virtual environment contained two versions of the virtual distributor: One version can self-assemble for demonstration purposes. This version also showed an image of the distributor manual. The other one can be assembled manually, using the navigation controls of DIVE, the computer keyboard and mouse. A distinctive sound was heard when each piece was assembled in its correct place, working as task feedback.

A demographics questionnaire with items about age, previous computing experience, etc., was applied as pretest. The System Usability Scale (SUS) questionnaire (Brooke, 1996) was applied as post test. It is a widely accepted as a valid usability questionnaire. The SUS consists of ten Likert-style scales, with five descriptors (1=Strongly disagree, 5=Strongly agree) to assess general usability of a computer system interface and its human-computer interaction, including computer interfaces for industrial applications. With the SUS questionnaire it is possible to calculate a general usability score, on a scale from 0 (very poor usability) to 100 (excellent usability).

Participants

Five mechanics from a local car and motorcycle repair garage (an SMB) tested the virtual environment. In a demographics questionnaire applied before the test, the mechanics reported that they had very little computing experience, with an average of age of forty-two years. However, the mechanics reported they had played video games occasionally and for a limited period during their adolescent years.

The test was carried out at the mechanics garage to ensure that they would feel comfortable in their natural place of work. We thought that if we did the usability test in an artificial environment like a computer room, this might cause additional stress that would affect their performance. This also ensured ecological validity to the test.

Procedure

Before the test started, each mechanic had allotted 10 minutes to try out the navigation controls and to familiarize with the virtual environment. The mechanics' tasks in the virtual environment were to watch how the virtual distributor was self assembled, and after that, each mechanic tried to assemble it manually using the computer keyboard and the mouse. There was unlimited time to perform this task.

Figure 5 shows one of the five mechanics who tested the virtual environment in DIVE, using a laptop computer in his repair garage. In addition, it was important to show them that computer technology could be practical tool in their workplace.

Figure 5. A mechanic interacting with the virtual engine distributor.

Usability Test Results

All the mechanics completed the test and averaged 40 minutes of interaction with the application. At the end of the test, each mechanic filled a SUS questionnaire. The score average of the five mechanics was 77.5, indicating that the virtual distributor VE rated well with them as far as usability is concerned. Although the number of mechanics that participated in the usability test seems low, it is possible to detect about 75% of the usability problems of a computer interface with just five users (Nielsen and Landauer, 1993). This by no means limits the number of usability tests that have to be done to obtain a completely usable and fully-fledged virtual environment for training. Most of the time, it is necessary to carry out various usability tests in an iterative fashion, as well as other complementary methods, which are not within the scope of this chapter. In our case, we had to develop three VE prototypes because we needed to correct some aspects of the distributor model and from the VE. Each prototype was previously tested with some engineering students and people from our research team. We chose to use the SUS questionnaire because it is simple to fill-in, to calculate the usability scores, and because it covers the subjective perception of about any system usability and interaction.

The ten Likert scales of SUS questionnaire (Brooke, 1996) are:

1. I think that I would like to use this system frequently.
2. I found the system unnecessarily complex.
3. I thought the system was easy to use.
4. I think that I would need the support of a technical person to be able to use this system.
5. I found the various functions in this system were well integrated.
6. I thought there was too much inconsistency in this system.
7. I would imagine that most people would learn to use this system very quickly.
8. I found the system very cumbersome to use.
9. I felt very confident using the system.
10. I needed to learn a lot of things before I could get going with this system.

Figure 6 describes a summary of the ten Likert scales that mechanics marked in the SUS questionnaire.

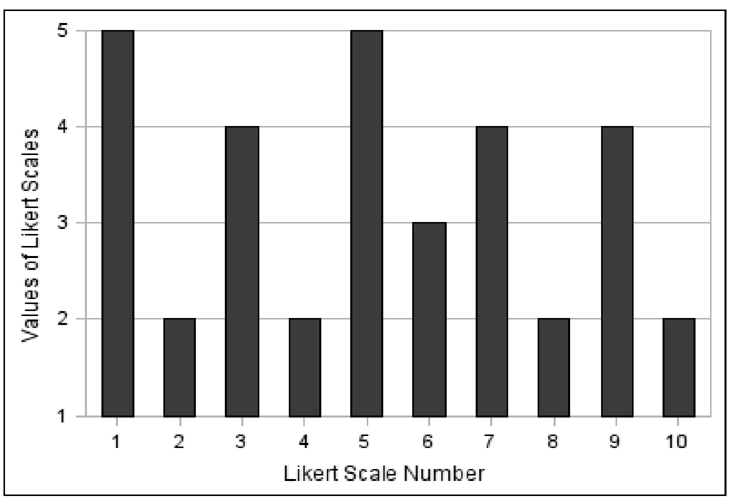

Figure 6. Average results of each Likert scale (1=Strongly disagree, 5=Strongly agree) from SUS questionnaire applied to the five mechanics.

In an interview done after the test, all the mechanics agreed that the virtual environment helped them to visualize the assembling process of the distributor, and they also agreed that the VE would serve to visualize the assembling of practically any auto part, especially for brand new parts they are unfamiliar with. Interestingly, after the usability test one of the mechanics suggested that the virtual environment used in the usability tryout may also be useful to show engine parts to customers at auto parts store desks. The test also showed that having a laptop with the virtual environment in the car repair garage is an unobtrusive and practical way for the mechanics to get technical training. There are cost-effective and fast usability methods that are intended to improve a computer interface, including virtual environments, such as the SUS questionnaire method used in this test.

In summary, the following shows the findings from the usability test with the five mechanics, where the three main usability aspects were covered (computer interface efficacy, efficiency and user satisfaction):

- Efficacy and usefulness. The mechanics truly believed that the virtual environment would help them very much in their work.

- Good level of acceptance and user satisfaction. The mechanics agreed that they would use the VE frequently, and were pleased of the VE design (colors, and other features).

- Good virtual environment general efficiency. The mechanics learned to use the virtual environment rapidly and were not confused with the virtual environment navigation controls.

It is important to note that the "novelty effect" may have influenced the test results, and it is necessary to run more usability tests with the virtual environment, especially with more participants, to confirm the findings, as well as longitudinal usability and learning studies with desktop VR are needed.

A Comparison of Second Life and DIVE

According to the usability tests we have done on DIVE and SL, and looking at the literature review on both, we have made a technical comparison of both VR programs. Table 2 summarizes a number of advantages and challenges of each program. Both programs are intended for general applications, where DIVE has been used mainly and largely for more than a decade on research, including VR research applications on education and training. Second Life has been initially orientated to edutainment applications, with recent applications in education and training. Recent research in these fields is beginning and the initial results are promising.

Second Life		DIVE	
Advantages	**Challenges**	**Advantages**	**Challenges**
● User registration at no cost. ● SL viewer (client) is open source. ● Variety of third-party viewers have been developed. ● Compelling graphics and sound effects. ● Variety of options for menu interaction and navigation. ● Easy to install. ● Binary (executable) versions available for various operating systems. ● Excellent for collaborative applications on the Internet (with adequate access and bandwidth). ● Program updated regularly. ● Chat, gestural and voice over IP (VoIP) communication possible among users. ● Extensive support and documentation from Linden Labs and from the Internet community.	● Needs efficient Internet access (>500Kbps). ● Needs certain types of robust graphics cards. ● Most educational applications can be used for a fee. ● Difficult to program. ● Do not run yet on a local network as stand alone*. ● Difficult to manage voice (VoIP) interactions. ● Server is not configurable.	● Users do not need to register. ● Open source (free for non-commercial applications). ● Compelling sound effects. ● Good for collaborative training in a local network. ● Excellent for training with stand-alone applications. ● Easy to program and configure. ● Easy to install. ● Binary (executable) versions available for various operating systems. ● Easy to insert 3D models in a virtual world. ● Server easily configurable. ● Chat, gestural and voice over IP (VoIP) communication possible among users.	● Not efficient with complex 3D graphical models. ● Not efficient with high resolution textures (images embedded in the virtual environment). ● Unstable when used collaboratively for Internet access. ● Avatar graphics need improvement. ● Few documentation and manuals available. ● Program not updated regularly. ● Limited support from its creators and from the Internet community.

Table 2. Advantages and challenges of Second Life and DIVE.

*Linden Lab announced in the Virtual Worlds London Conference held on October 2008 that this company is developing a stand-alone SL version (Linden, 2009). It will run on a local server and on a local area network (LAN), which currently is in the development stage and is expected to be released to the general public in the summer of 2009. It seems that this stand-alone version will only be commercially available only, and will be intended mainly to support business organizations, education, and training.

The main technical differences between DIVE and SL are the network performance and the minimum hardware requirements. DIVE currently can run on both slow and fast networks, using the Internet for collaborative applications and as stand alone in a local network, requiring almost any type of recent personal computers, whereas SL works smoothly only on fast networks, fast Internet access, and on fast computers with certain types of graphics cards. However, the graphic aesthetic appearance of SL's virtual worlds and their contents is superior to DIVE's.

It is important to note that there are differences about VR adoption between SMBs and large companies. According to past literature on technology use in SMBs (Wierzbicki & Margolf, 2002) among others, it appears that the main difference regarding whether or not small businesses adopt VR is its cost-effectiveness. Large companies, however, tend to purchase more expensive fully-immersive VR equipment, and pay sometimes extremely high maintenance costs.

Future Trends

We foresee that in the future, expensive simulators and fully-immersive virtual reality will continue to be used by the military, large companies and by very specialized training programs that require hands-on skills. However, for the foreseeable future, semi-immersive (desktop) VR technology that use fewer resources and can be programmed by people with fewer computer programming skills, will have a growing demand in both education, training and different government and economic sectors, particularly those who do not have the resources to purchase, maintain and optimally exploit traditional fully-immersive systems. Some of the latter VR programs will be used by SMBs operating in developing countries with limited Internet access as well.

Another issue that will be worth investigating in the future is how workers actually adopt to VR technology in SMBs. Although there are extensive studies in the literature about technology adoption in general, for example see Norman (1998), it could be interesting to see whether the learning curve, integration, acceptance, likeness, adaptation, motivation, and other issues change over time and among SMBs, as well as for larger companies.

To improve the effectiveness of VR for training, it will be necessary to carry out more research on developing more easily usable VR training platforms. One of the key challenges will be to design and adapt VR hardware and software that will support full accomplishment of training objectives. This can be done by developing easy to use, unobtrusive, pleasurable, and efficient VR applications that employ software engineering methodologies in the design and application of VR for training (Tromp et al., 2003; Stanney, 2002).

Augmented reality (AR) technology is a step beyond desktop virtual reality. It will have a significant impact on training procedural skills in many applications. AR is the combination of computer-generated data in three dimensions (computer graphics) and real-world data (Azuma, 2001), complementing human information processing and cognition in training (Neumann and Majoros, 1998). One of its main characteristics is that it is interactive and functions in real time. This technology has been successfully used by the military to train soldiers and pilots (Brown et al., 2006), and research is currently underway on how to better use desktop AR to train people in other applications. Recent developments include cost-effective and portable AR devices, for example, see Olwal & Hollerel (2005). Facilitating acquisition of specialized technical skills in SMBs by using AR will need to be explored.

Conclusion

In conclusion, the objective of this chapter was to depict an overview on how virtual reality can be used to support technical training in SMBs, including the use of Second Life and DIVE virtual reality software platforms. We also showed similarities and differences between a commercial (SL) and open source (DIVE) typical VR platforms, both of which are programmable and support participant collaboration and are suitable for training applications. The chapter also described a desktop VR Application for training car mechanics from a small business. According to recent research and developments in the area of virtual reality training and education, it appears that open source software will have an important role in developing and applying virtual environments for training personnel in SMBs, due mainly to economic and technical reasons. Key factors for small and medium-size businesses to adopt desktop (semi-immersive) VR technology include efficient virtual reality interfaces, adequate use of computer resources (including a reliable network and Internet access) and user satisfaction. Thus, there must be a balance between graphics realism and hardware/software efficiency in collaborative virtual environments for training. VR can be successfully used for training purposes, provided that skill transfer support is adequately and systematically carried out with VR, taking into account both technological and social aspects. Virtual reality technology should be just a medium to support training and not an end in itself, therefore its usability should be high enough to avoid hindering training objectives.

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Key Terms and Definitions

Collaborative Virtual Reality: A shared virtual environment using a local network or the Internet, where its users interact to work, learn, train, and perform other activities together.

Competency: The sum of knowledge, skills and characteristics that allow a person to perform an action successfully.

Human-Computer Interaction (HCI): Discipline concerned with the design, evaluation and implementation of easy-to-use, productive, safe and interactive computer interfaces for human use, and the study of its context of use.

Network Latency: Network delay, consisting of how much time it takes for a data packet to get from one designated point to another in a computer network.

Second Life: A networked virtual reality environment shared by millions of registered users, using the Internet as a communication medium.

Service Level Agreement (SLA): a negotiated agreement between a customer and an Internet service provider to guarantee a minimum of bandwidth provided, quality of service (QoS), etc.

Small and Medium-sized Businesses (SMB): A type of business with less than 500 employees.

Usability: Measurement of the ease of use of a computer interface, based mainly on its efficiency, efficacy, and pleasantness of use.

Virtual Environment: A computer-generated 3D space (also called virtual world or metaverse) where 3D graphical objects and sounds reside. Its user is represented by an avatar (a graphical personification) and can interact with the virtual objects and its environment.

Virtual Reality: Computer technology capable of generating a three-dimensional space called virtual environment, which is highly user interactive, multimodal, and immersive.