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Building interactive virtual environments for simulated training in medicine using VRML and Java/JavaScript

D. Korošec*, A. Holobar, M. Divjak, D. Zazula

University of Maribor, Faculty of Electrical Engineering and Computer Science, Smetanova 17, 2000 Maribor, Slovenia

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Summary Medicine is a difficult thing to learn. Experimenting with real patients should not be the only option; simulation deserves a special attention here. Virtual Reality Modelling Language (VRML) as a tool for building virtual objects and scenes has a good record of educational applications in medicine, especially for static and animated visualisations of body parts and organs. However, to create computer simulations resembling situations in real environments the required level of interactivity and dynamics is difficult to achieve.
In the present paper we describe some approaches and techniques which we used to push the limits of the current VRML technology further toward dynamic 3D representation of virtual environments (VEs). Our demonstration is based on the implementation of a virtual baby model, whose vital signs can be controlled from an external Java application.
The main contributions of this work are: (a) outline and evaluation of the three-level VRML/Java implementation of the dynamic virtual environment, (b) proposal for a modified VRML `TimeSensor` node, which greatly improves the overall control of system performance, and (c) architecture of the prototype distributed virtual environment for training in neonatal resuscitation comprising the interactive virtual newborn, active bedside monitor for vital signs and full 3D representation of the surgery room.

1. Introduction

Learning and training using computer-based systems helps improving knowledge and skill acquisition process in many fields. Medicine is no exception [1]. Even more – as a field dealing with particularly delicate objects, namely human beings, it is often inherently limited with respect to training possibilities. There is usually little room for errors and exercise with real patients, who are expecting expert treatment instead of novices.

Traditional medical education has two stages: theoretical study and hospital apprenticeship. There is a gap between the two which could be closed by learning and training in simulated conditions so as to avoid 'learning by accident'

*Correspondence to: D. Korošec. Tel: +386 31 321 921.
E-mail: dean.korosec@uni-mb.si (D. Korošec)

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phenomena. Computer based devices and software used in such training are often called computer simulators, although this is a very inexact term, as it should cover everything from, for example, tens of thousands dollar worth patient simulators capable of realistic gas exchange, blood flow and heart activity; over complex simulation devices for surgical and endoscopic procedures; down to software-only models and study tools or small programs for visualisation of pharmacokinetic graphs, and more [2].

In general two kinds of simulations should be distinguished first: (a) 'real-world' simulated situations, and (b) virtual environments (VEs) based on computer models and animations. With both approaches, students should work through predefined scenarios and training tasks, although involving a mentor to supervise such training is in both cases necessary to provide higher complexity and realistic assessment.

A good example of training using simulated exercises is the system of crisis management training in neonatal resuscitation [3] introduced by L. Halamek, D.M. Gaba and their team at the Veterans Affairs Palo Alto Health Care System [4]. It can provide a significant degree of immersion and a very realistic experience, but the price is high: special training facilities with instruments, monitors, mannequins, and skilled senior staff to control and supervise the training are necessary. A virtual environment alone can not completely replace such experience, but it can help students to be better prepared for such situations and thus make the whole process more efficient. The two approaches are complementary - while certain skills (e.g. intubation, heart massage, etc.) can be better trained with real equipment and mannequins, others (for example assessment of vital signs) can be more realistically pictured using interactive 3D graphics. We believe that modern medical education should include all four mentioned stages of the learning path, as shown in Fig. 1.

Let us now focus on applications of virtual reality (VR) technology, which received a lot of attention some years ago with the development of cheap computer power and prevalence of the Internet. Medicine has traditionally been one of the major application fields for VR, with medical education being the first area in which it made significant contributions. Others include remote and local surgery, surgery planning, treatment of phobias and other causes of psychological distress, skill training, pain reduction, and more [5].

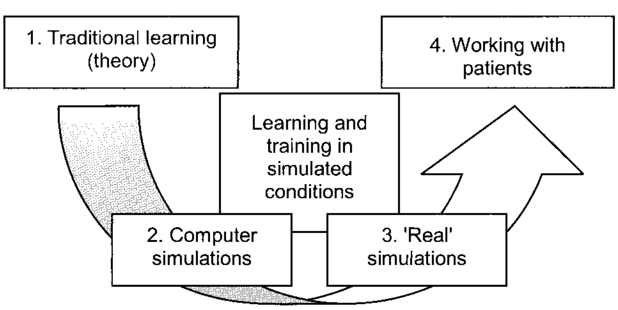

Fig. 1. Learning and training in simulated conditions can close the gap between theory and practice in medicine.

On the other hand, one has to admit today that VR in general has not quite lived up to its initial expectations. Why don't we see more VR-based systems in our professional activities (not to mention daily lives) yet? While one reason is certainly that VR hardware is still extremely expensive and immature, we believe that the main reason for such situation is the lack of good software standards and their efficient implementation on common computer platforms. Practically only one such solution, Virtual Reality Modelling Language (VRML) [6], exists currently for building open standard applications. Most VRML applications that have been built using this open standard for Web VR are still mainly static visualisation of 3D objects and perhaps some simple animations. While their educational value should, of course, not be underestimated, as many excellent examples also in the field of medicine and biology demonstrate [7], the full potential of VRML lies further ahead.

In the past, we have carefully studied VRML and used it to create various virtual environments. Our challenge and aim has always been to make them as dynamic and interactive as possible, because we believe the success of experience with virtual environment is strongly related to these two components. The culmination of our efforts is a virtual delivery room [8], which we designed to support training of proper procedures in resuscitating newborns.

This paper presents some aspects and lessons learned while implementing a dynamic 3D representation of vital signs of a virtual newborn [9] with VRML, and is organised as follows: after briefly introducing a three-level scheme for implementing the dynamic interactive virtual environment in the following section, we present the main content in the third section, where we describe (a) the performance issue of the VRML `TimeSensor` node and its solution, (b) the virtual newborn as the main object, and (c) the complete architecture of our system for training in neonatal resuscitation. In the last section some conclusions based on our experiences are given together with a brief announcement of the X3D standard, which will soon replace and extend VRML.