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virtual laboratories. It provides an application that can be used by a non-technical user (i.e. teacher) and is re-configurable (i.e. generic and adaptable). The

framework developed in this study also provides an educational model and content

"Virtual education will enable us to ask and answer many fundamental questions about the nature of our existence"

- J. Canton 1999 [52]

Conclusions and Future Work

6.1 Conclusions

This thesis focuses on applying virtual laboratories in an educational setting. Although virtual laboratories have been used in an educational setting with great results, the development of many of these applications is costly, and often expensive when immersive and projection based virtual reality is used. In addition these virtual laboratories are usually of fixed implementations that require programming and a technical background.

The Intelligent Tiles (iTiles) framework developed in this study attempts to overcome many of the above-mentioned limitations of virtual laboratories. It is a generic and adaptable framework that supports teacher driven development of virtual laboratories. By using this framework, virtual laboratories can easily be authored and be used in the education of young learners in teaching topics in earth science, such as ecosystems. The iTiles Ecosystem Virtual Laboratory is a virtual reality application implementing the iTiles framework. This application has the advantage of being affordable, since it is developed for a desktop virtual reality solution, considered the least expensive and most widely used of all virtual reality platforms. With simulations of virtual laboratories using the iTiles framework, young learners can explore, understand and gain mathematical skills such as counting, sorting and classification as well as learning ecological concepts and relationships between different animals and plant life. For example, the 'Drought in Africa' virtual laboratory produced with

this application teaches children about the desertification of an African savannah during a harsh drought.

This thesis proves that it is possible to apply a cheaper virtual reality platform such as Desktop VR, and achieve a user-friendly (teacher and learner friendly) product of high quality. It presents a framework for virtual laboratories attempting to address many of the major problems related to virtual laboratories. It provides an application that can be used by a non-technical user (i.e. teacher) and is re-configurable (i.e. generic and adaptable). The framework developed in this study also puts emphasis on educational needs and content, resulting in an educationally viable product.

One of the key advantages of the application developed using the Intelligent Tiles approach of this thesis, is that it is user friendly. The Intelligent Tiles Framework encapsulates both teacher and learner roles for teaching and learning with virtual laboratories. It also considers the elements of a virtual environment, with simple abstract concepts, which are easy to grasp. Authoring a virtual world from simple components such as tiles and world objects does not add much complexity to the world. The qualities and attributes of world objects bring the simulation of the world to life. The generic and adaptable approach of the framework is aimed at ease of use and extensions.

This study also indicates that by using a well-designed framework it is possible to translate an educational concept into useful applications. The iTiles Ecosystem Virtual Laboratory is implemented in C++ using the open source libraries OpenGL and OpenAL. This application proved that one could implement the Intelligent Tiles framework and concepts in a manner in which the teacher driven development of further virtual laboratories is possible without the need for special technological skills. The simulation of a virtual laboratory authored by a teacher can be used in the education of young learners, where learners can learn by experiencing and learn by doing. The 'Drought in Africa' virtual laboratory presents an example of a virtual laboratory produced using this application. Lesson objectives and educational content were realised with this virtual laboratory.

The iTiles framework and VR applications show that complex ecological concepts regarding eco-conservation could be thought to young learners by employing simple simulations. In this way, learning a complex concept becomes 'fun' rather than unreachable abstract.

The iTiles Ecosystem Virtual Laboratory application has been successfully tested on windows operating systems and a user manual has been written for ease of use (available in Appendix C).

Based on the work carried out in this thesis a publication was presented in a recent international conference on computer graphics [39].

6.2 Future Work

The Intelligent Tiles framework and the iTiles Ecosystem Virtual Laboratory can be extended and improved. In this section such extensions and improvements are suggested.

The Intelligent Tiles Framework currently accommodates a single layer of tiles. By adding another layer of tiles the system can be improved. For example, adding an additional layer of ‘invisible’ tiles above the original layer, can represent the sky. World objects such as clouds and a sun can be added to this new layer. These world objects can trigger world transformations to occur on the world objects and tiles in the layer below. For example, a cloud could rain occasionally causing trees below to grow.

The Intelligent Tiles Framework has been applied in building virtual worlds with an ecological nature, in the field of earth science. This type of ecological world is dependent on the tiles and world objects that are added to the system. One can consider using the iTiles framework in other fields. For example, using the iTiles concepts in a field such as agriculture and forecasting, tractors and sheep can be added as world objects.

The iTiles Ecosystem Virtual Laboratory currently has a non-user friendly mechanism for extending the iTiles system interfaces, for adding new world objects and world sounds. To make it easier for a user to add additional world objects and sounds to the system, an additional tool for the visual representation of these iTiles interfaces can be implemented. This will help in determining the best scaling for a world object on a tile, and easy maintaining of the interface library. To improve the educational experience and content the world object interface can also be extended to include more information about world objects. For animals represented by dynamic world objects, textual information or multimedia videos on the ecological habits and habitats of these animals would be beneficial to students.

In improving the iTiles World Flow tool for specifying the behaviour of an iTiles world, one can modify the input screens to be pictorial or in words, so that young learners too could set

the behavioural properties of an iTiles world. Eliminating or abstracting the numeric attributes of the iTiles World Flow can also be considered, as indicated by the fuzzy logic representation in Chapter 3.

The iTiles Ecosystem Virtual Laboratory application has been implemented on a Windows platform. Portability to other operating systems such as Linux can be considered since the implementation has adhered to an ANSI C standard and uses the open source libraries OpenGL and OpenAL.

The iTiles framework is currently focussed on standalone a VR system. An investigation into extending this into a collaborative virtual environment can be considered. Collaborative authoring of an iTiles world, and collaborative experiencing and participation of the simulation of an iTiles world would be a great enhancement. Students at different locations around the world could “learn together” about a certain world even though they are separated geographically by a vast distance. Such a collaborative system would involve sharing the iTiles system interfaces. A central database can be considered, from which world objects and tiles could be downloaded, as to retain unique identification in each independent iTiles system.

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