Virtual Bicycle: An User Interface Tool for Navigation in Virtual Worlds

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ABSTRACT

One of the most complicated tasks when working with three-dimensional virtual worlds is the navigation process. Usually, this process requires the use of buttons and key-sequences and the development of interaction metaphors which frequently makes the interaction process artificial and inefficient. In these environments, very simple tasks, like look upward and downward can became extremely complicated. To overcome these obstacles, this work presents an interaction model for three-dimensional virtual worlds, based on the interpretation of the natural gestures of a real user while he/she is walking in a real world. This model is an example of a non-WIMP(Window, Icon, Menu, Pointer) interface. To test this model we created a device named **virtual-bike**. With this device, the user can navigate through the virtual environment exactly as if he were riding a real bike.

KEYWORDS:

virtual reality, non-WIMP(Windows, Icon, Menu, Pointer) interfaces

RESUMO

Uma das tarefas mais difíceis quando se trabalha com mundos virtuais tridimensionais é a **navegação**. Em geral, este processo envolve o uso de botões e teclas e a criação de metáforas de interação que tornam o processo pouco natural e de eficiência reduzida. Neste ambientes, movimentos simples como baixar ou elevar a cabeça, andar para o lado ou para frente, tornam-se complicados e pouco naturais. Exemplos disto são os muito conhecidos navegadores Nestcape, Virtus, Internet Explorer, Worldtoolkit e outros. A partir desta dificuldade este trabalho desenvolveu um modelo interação para mundos virtuais tridimensionais baseado na interpretação dos movimentos reais do usuário. O modelo constitui um exemplo de interfaces do tipo non-WIMP(Window,Icon,Menu,Pointer). Para testar o modelo implementou-se um dispositivo(**bicicleta virtual**) a partir do qual o usuário pode navegar por um ambiente exatamente como se estivesse passeando de bicicleta.

PALAVRAS-CHAVE

Realidade Virtual, Interfaces não-convencionais

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1. INTRODUCTION

With the coming of real-time graphic libraries as OpenGL and Direct3D (WOO 1997, WOO 1998), the exhibition of three-dimensional synthetic environments that, visually, are very similar to the real ones, have become possible.

When the interaction needs in these **virtual environments** are small and the main tasks are restricted to the exhibition of objects and its manipulation with rotation and translation operations, the problem seems to be resolved. Besides, when the interaction tasks are limited to the navigation along pre-defined paths, there is still not a problem.

However, when it is necessary to do fast and natural **navigation** in an environment similar to the real world, some problems appear with the user interface tools available nowadays. In general, this navigation process involves the use of buttons and keys and the creation of interaction metaphors which makes the process not much natural and of reduced efficiency.

In these environments, simple movements as to lower or to elevate the head, to walk to the side or forward, become very complicated and a little unatural. Examples of these are the very well-known navigators Nestcape, Virtus, Internet Explorer, Worldtoolkit and others. This happens, mainly because in this case we are using the traditional WIMP(**W**indow, **I**con, **M**enu, **P**ointer) interface paradigm, in essentially three-dimensional applications, where the user's body is an important part of the interaction process.

With the advent of virtual reality, the interface forms between human and machine had a great evolution in terms of quality (Pinho 1997). That increment in the quality of the interface has its explanation in the fact that the virtual reality provided more intuitive manners the users to interact with the systems, without the need of control buttons or other resources for the interaction (Paush 1998, Mine 1995).
In this work we create an interface model that tries to accomplish the human-computer interaction in a more direct way. The **central idea is to map each user's gestures directly to movements** inside the virtual world, without requiring memorization of metaphors and sequences of buttons to interact in the environment.

1.1 Virtual environments

A virtual environment can be seen as a dynamic three-dimensional scenery, modeled through computer graphics techniques and used to represent the visual part of a virtual reality system. The virtual environment is nothing else than a scenery where the users of a virtual reality system can interact.
An important feature of a virtual environment is to be a dynamic system. In other words, the sceneries are modified in real time as the users interact with then. A virtual environment can be projected to simulate an imaginary environment as close to the real one as possible.
Also denominated "virtual worlds", those environments can be modeled through special tools, in which, the most popular is VRML (Clark 1996, Hardenbergh 1998, Siggraph 1995). The interaction degree in a virtual environment will be larger or minor depending on adopted interface, besides the devices associated to the system.

1.2 User Interfaces in Virtual Environments

The virtual reality comes to bring a new user interface paradigm. In this paradigm, the user is not more in front of the monitor, but, he must fell **inside the interface.** With special devices, virtual reality tries to capture the user's movements(in general arms, hands, and head) and, starting from these data, it tries to accomplish the man-machine interaction. The interface in a Virtual Reality system tries to be similar to the reality, trying to generate the **sensation of presence** (Slater 1994) in a three-dimensional synthetic environment, through a computer generated illusion. This sensation, also called **immersion (**Greenhalgh 1997, Dourish 1992, Durlach 1998) is the most important characteristic in Virtual Reality. The quality of this immersion, or the illusion degree, or how real this illusion seems to be, depends on the **interactivity** and on the **degree of realism** that the system is capable of providing.
The **interactivity (**Forsberg 1998) is given by the capacity that the system has to give answers to the user's actions. If the system answers in an instantaneous way, it will generate in the user the feeling that the interface is *alive*, creating a strong sensation of reality. For this reason, the virtual reality is a computer system that should use real time techniques for the user interaction.
The **degree of realism,** in its turn, is given by the *quality* of these answers. The more similar to a real scene it is(presenting an image or emitting a sound), the more involved the user will be.

1.3 Interfaces non-WIMP

The ***non-WIMP interfaces*** are characterized by involving the user in a continuous and parallel interaction with the computational environment. They are those kind of user interfaces that do not depend on interface objects to be accomplished (Vam Dam 1997, Morrison 1998). The main idea is to have interfaces that involve the user in a complete way, interpreting all his gestures(head, body, eyes, arms gestures) through special devices. This interpretation should be continuous and parallel and the generation of sensations on the user should reach all his senses, including those ones usually used(vision and audition), but still adding the possibility of generating sensations such as touch and strength, as well as others as cold and heat, for instance.
Today, the most developed form of ***non-WIMP*** interfaces are three-dimensional virtual reality environments. In these environments, we have a constant updating of the images presented to the user and, in response to any user movement, an answer can be generated.

2. THE PROPOSED INTERFACE MODEL

2.1 A model without Navigation Metaphors

Analyzing the problems presented in the previous section, we created an interface model that tries to accomplish the human-computer interaction in a more direct way. The **central idea is to map each user's gestures directly to movements** inside the virtual world, without requiring memorization of metaphors and sequences of buttons or keys to interact in the environment.
As other studies have already shown, a very generic interface tends to become difficult to use in specific complex applications (Cooper 1997, Schneiderman 1998). For this reason, we decided to define a model to treat the specific

problem of navigation. We did not worry, in the model, with the problem of object manipulation.

2.2 The available movements

By observing a cyclist's movements while he rides through a city, we have identified a group of movements that are usually executed to analyze a place:

- To look to the sides, upward, down or back;
- To approximate the head of an object to observe it in detail;
- To walk forward;
- To stop the movement;
- To change the direction of the movement;
- To increase and to reduce the speed of the movement.

A cyclist was taken as base, however, we could have opted for other movement forms, like walking or driving a car. We chose the cyclist for two reasons: in the case of walking the movements are slow; in the case of driving a car, the possibility of the details analysis (interaction with the environment) is reduced.

2.3 User Interface Actions

Starting from the identification of the user movements in the real world, which we named **Goals**, we defined a set of movements this user should accomplish on the interface, in order to execute his tasks.
Based on this, the relationships shown on the table 1, were defined.

3. TESTING THE USER INTERFACE MODEL

In order to test the proposed model, a navigation device was built based on the interpretation of a bicycle’s movements and on the exhibition of images using a virtual reality HMD(Head Mounted Display). To do this, we adapted a set of sensors on a bicycle and by reading these, we accomplished the movement.
After building the prototype device we developed a group of tests in order to evaluate in practice, if this device makes the navigation easier or not, and if the model can be considered valid for the target application.
In the following sections we present details about the prototype construction and about the tests accomplished.

3.1 Virtual bicycle – The Test-tool for the User Interface Model

The built prototype is a real bicycle that was hanged up on a tripod allowing to pedal it without moving. To capture the movements of the handlebar we attached a potentiometer on it. The speed of the movement was read by a dynamo coupled to the wheel. The movement of the user's head was captured by a position tracker. The prototype’s architecture can be seen in the figure 1.

3.1.1 Reading the Bicycle and User’s movements

To read the data from the bicycle, two sensors were used. One of them attached to the handlebar(a potentiometer) and the other attached to the bicycle’s wheel(a dynamo) (figure 2).

Goal	User movement on the interface
To look to the sides, upward, down or back	To move the head
To approximate the head to an object to observe it in detail	To move the head
To walk forward	To pedal
To stop the displacement	To stop
To change the direction of the movement	To rotate the handlebar
To increase and to reduce the speed of the movement	To pedal faster or more slowly

Table 1 – The user's goal *versus* user movements

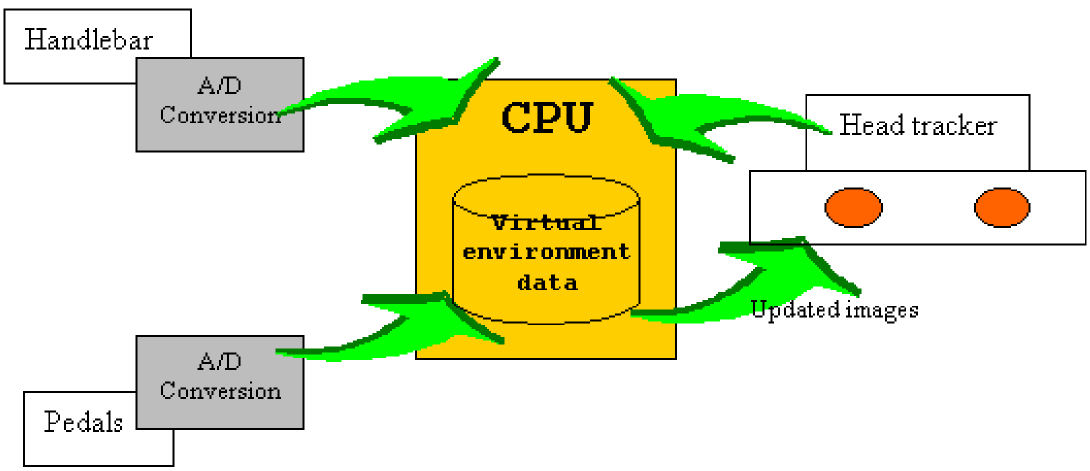

Figure 1 – The Prototype Architecture

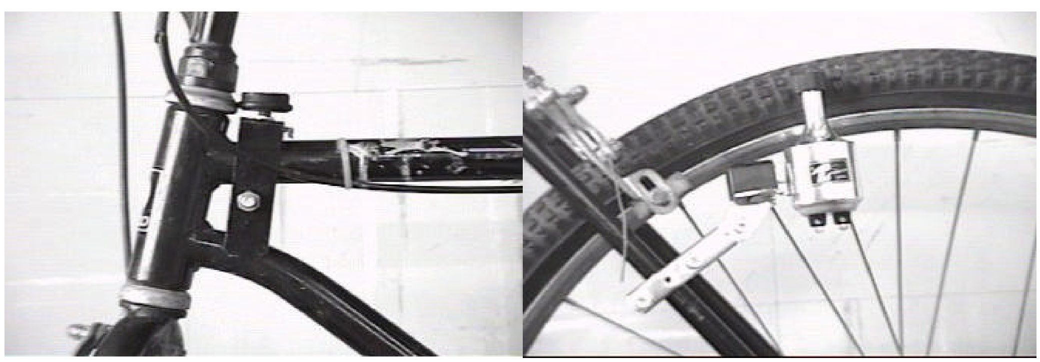

Figure 2 – Movement sensors attached to the bicycle

The analog/digital signal conversion was done through an equipment called TNG-3 Interface (Mindtel 1999). The connection of the TNG-3 and the computer is made via serial port. To accomplish the user's head movements interpretation, we used an ISOTRACK II position tracker, from Polhemus (Polhemus 1999).

3.1.2 Exhibition of the Sceneries

The displayed three-dimensional images try to simulate a city where the user can navigate. For the exhibition of this three-dimensional scenes, the OpenGL graphics library (Woo 1997, Woo 1998) and the virtual reality HMD called IGlasses (I-Glasses 1999) were used.

The cities used were modeled with an editor specifically created for this task. In figure 3 a user's view can be observed. It is important to notice that there are no controls or menus on the interface, just the three-dimensional images.

3.2 Modeling the Cities

In order to allow the navigation and the execution of detailed tests, we decided to model our own validation sceneries. For this task we created the *City Editor* (Braum 1998). This tool allows the fast creation of small cities. They are cities with streets, buildings and trees. These entities were considered enough to give to the user the visual sensation of a city. The Editor allows to save cities in VRML and DXF file formats. Figure 4 shows the Editor's screen and the visualization of a city in a VRML navigator.

3.3 The Methodology of the Validation Tests

The evaluation of the proposed user interface model was done comparing the results of the use of the model and use of a commercial navigator, like Internet Explorer. In figure 5 a user during a test can be observed.

In order to test the proposed model and the built device, some tasks, which the user must execute, were defined (Bowman 1998). These tasks were the following:

- To walk on a defined path;
- To look for a defined object;
- To recognize the objects of the environment after a navigation;
- To return to a certain point of the city;
- To analyze details in a specific part of the city.

Starting from these tasks some parameters were defined in order to evaluate if the model is useful (or not) to accomplish the tasks.

The tasks and their parameters can be seen on the table 2.

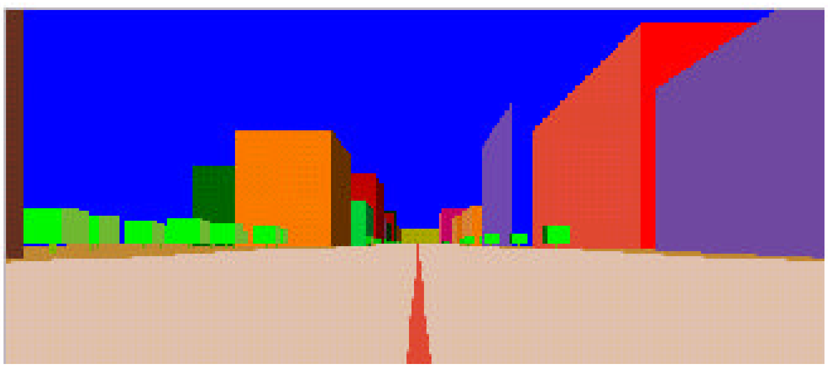

Figure 3 – Example of the user's view

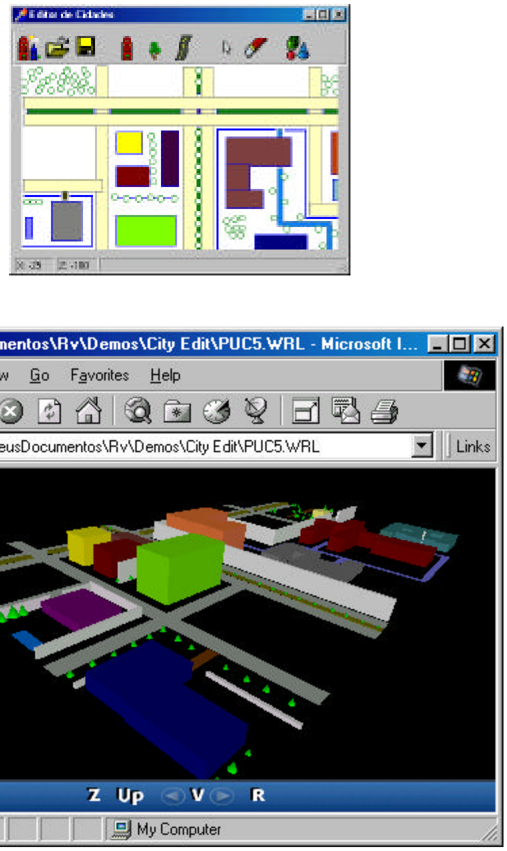

Figure 4 – The City Editor

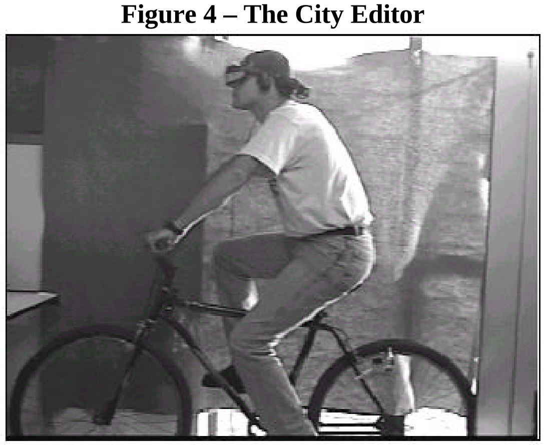

Figure 5–User in the Virtual Bicycle

Tasks	Parameters
To walk on a defined path;	Total time spent
	Level of difficulty
To look for a defined object	Total time spent
To recognize the objects of the environment after a navigation	Number of recognized objects
To return to a certain point of the city	Total time spent
To analyze details in a specific part of the city	Level of difficulty

Table 2 – Tasks and their respective Parameters

To apply the tests, a group of 2(two) cities were chosen and it the following tasks were defined:

a) Go straight ahead, turn right on the third street and turn left after the green building;

b) On the third street on the right there is a white box behind a building. Try to find it;
c) Walk on the two streets on the right side of this avenue. (When the user returns we asked him: Do you remember how many trees you have seen ?)
d) Try to find the white box of the task b) again;
e) Read what is written in the plate in front of that red building.

These tasks were performed by the 16 users in the following way: half of them used the Internet Explorer first and the other half used the Virtual Bicycle first. This was made in order to evaluate if the previous knowledge of the scenery could affect the user's performance.

3.4 The Results of the validation tests

The results obtained in the development of each task are expressed in the tables 3 to 7.

The order in which the interfaces was used did not alter the results of the tests.

4. CONCLUSIONS

In a general way the obtained results were quite positive for the proposed model. In most of the cases the developed tool was very superior to the existent commercial navigators. Even for expert users on three-dimensional navigator(7 on 16) the use of the proposed tool was considered very efficient.

Some users noticed that they felt tired and uncomfortable in having to pedal.

Some users found the HMD image quality unsatisfactory. The used resolution is limited to 640x480 by the equipment.

The best results obtained with the user interface model were in the test of "To analyze details in a specific part of the city". This is due mainly to the fact that with the built tool, the user just needs to move the head to look closer to an object, without the need to use key combinations or other artifices.

It was also noticed that the user movements were much softer with the use of the proposed model.

We are now beginning to undertaken studies to treat the problem of direct manipulation of three-dimensional as well objects using virtual reality techniques.

Parameter	Bicycle	Navigator
Total time spent (on average)	25 s	40 s
Level of Difficulty		
Easy	25.00%	18.75%
Medium	62.50%	43.75%
Difficult	12.50%	37.50%

Table 3 – Task A - "To walk on a defined path"

Parameter	Bicycle	Navigator
Total time spent (on average)	28 s	35 s

Table 4 – Task B - To find for a defined object

Parameter	Bicycle	Navigator
Percentage of successes	75%	50%

Table 5 - Task C - To recognize the objects of the environment after a navigation

Parameter	Bicycle	Navigator
Total time spent (on average)	20	35
Gain in relation to first time	20.00%	12.50%

Table 6 - Task D - To return to a certain point of the city

Parameter	Bicycle	Navigator
Level of Difficulty		
Easy	68.75%	37.50%

Medium	18.75%	31.25%
Difficult	12.50%	31.25%

Table 7 – Task E - To analyze details in a specific part of the city

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