The Navigation Wizard: Helped Metaphor-Aware Navigation in Virtual Worlds

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Abstract

Anyone who has ever experienced 3D interfaces will agree that navigating in a 3D world is not a trivial task. The user interface of traditional 3D Browsers provides simple navigation tools that allow the user to modify the orientation, position and focal of the virtual camera. Using these tools, it is common that after some movements, the user is lost in the virtual space and tries to restart from the beginning. This paper presents how this problem is addressed in the context of the CyberNet project [1]. Our underlying principle is to help the user to navigate by adapting the navigation tool to the virtual world.

Keywords: Virtual Worlds, Information Visualisation, Navigation, Interaction, 3D Graphics.

1 Introduction

The CyberNet framework is based on metaphoric virtual worlds. We use metaphoric worlds since the underlying structure of the world is familiar to the user. We have designed real world metaphors such as a building, a city or a solar system. We also have designed more abstract metaphors such as a cone-tree or an information landscape. Metaphoric worlds are built from predefined graphical components arranged hierarchically (e.g. cities are made of districts, districts are made of streets and buildings, buildings are made of floors that are made of corridors and offices, etc.). We believe that the built-in navigation schemes that are available in most current 3D browsers are too generic. Navigation can be improved by adapting the navigation schemes to the virtual world and to the user's tasks. When the user navigates from office to office in a virtual building he does not use the same navigation mechanisms that when he is exploring a landscape of data or studying the topological structure of a cone tree. This belief led us to the concept of *metaphor-aware navigation*, that is, the navigation is tightly bound to the visual metaphor used and the way the user moves in the virtual world is constrained by the metaphor that the same world is based upon. We also believe that the way a user navigates in a 3D world is intimately related to the task that he pretends to accomplish. This paper exploits the concept of metaphor-awareness related to 3D navigation and presents the CyberNet metaphor wizard. We focus on the 3D navigation using standard user interface tools (i.e., a mouse and a keyboard); we do not address specific problems and solutions related to immersive navigation.

2 Previous work

Several research works have already addressed the subject of 3D navigation, focusing different navigation issues and using different approaches. Some of this research work deals mainly with viewpoint manipulation. There is also research addressing the specific subject of spatial knowledge and position awareness. Other research focuses primarily on constrained navigation. This sections presents some previous work regarding these three questions.

[2] reports most of the work already done on viewpoint manipulation. Navigation tools can be classified as being egocentric (moving a viewpoint through the world) or exocentric (moving the world in front of a viewpoint). They are also classified in terms of general movement (exploratory), targeted movement, specified coordinates movement and specified trajectory movement. Most of the navigation tools implemented by, for example, VRML browsers fall in the egocentric category [3] and the movements allowed have names such as fly, pan, walk or examine. General movements require to fix all the parameters but one, and to let the user modify the value of that specific parameter using the mouse or the keyboard. Some targeted movements (such as “fly to” with direct selection of the target or “jump to” with selection in a list of view points) are already supported. Although they may exploit the 3D world to simulate gravity or collision, these navigation mechanisms are completely independent of the virtual environment itself.

On the subject of providing spatial knowledge to the user, [4] has classified spatial knowledge in three classes: landmark knowledge (being able to identify positions using visual cues), route knowledge (having a knowledge of spatial relationship between visual cues) and survey knowledge (having a global spatial understanding of the environment). For position awareness, different kinds of solutions have been investigated. The main idea is to provide visual feedback of the user position. The simplest feedback scheme is to permanently display the 3D coordinates position of the user. This solution is not of great help especially because this position only has a meaning if the user already has an in-depth knowledge of the world geography. More elaborated solutions are based on the display of a global, simplified view of the world added in the user’s field of view. [5] proposes the concepts of “World in miniature”. [6] studied how 2D maps could help users to navigate in virtual buildings. [7] presents the concept of “map view”, a tool that allows the user to monitor his position (viewed from some “satellite” position) on a small virtual screen embedded in the 3D world. Although there are differences among these methods, the basic idea is to include -in front of the user- a small overall view of the world and a marker showing the position of the user in that world. For orientation awareness, [8] has pointed out the importance of knowing the vertical direction and presented some “upward” cues such as ground planes, backdrops and directional illumination.

Allowing a user to navigate freely in the environment is important, but most of us have experienced that being “as free as a bird” is not that easy. Research has been done in order to enhance the navigation activity by taking into account the goals of the user. The solution is generally referenced by the term "constrained navigation". Although it is true that these methods generally put constraints on the user movements, we prefer to use the term "helped navigation". [2] reports some early work toward that direction. [9] presents the "tracking viewpoint"; the idea is to modify the user's direction of view in order to allow the user to track a specific object (potentially moving) in the scene. This idea was also presented in [7] for tracking the user position in order to control the "map view". [10] presents a tool that constrains camera movements so that the position is limited to a surface and the orientation is dependent upon the surrounding objects. This study has been done mainly in the context of terrain navigation. The authors conclude that this kind of help tools should be context-dependent, state-dependent and history sensitive.

3 Navigation tasks

For the user's movements to be efficient, it is important for the user to have a spatial knowledge of the environment and a clear understanding of his location. Much effort as been put in the "wayfinding" tasks [11]. The interest on this topic is mainly related to virtual reality immersed interfaces. Wayfinding is obviously not the only task a user may want to do when navigating in virtual spaces [12]. In complement to "be as free as a bird", which should be always possible, following are several user tasks related to our field of interest (we do not pretend to be exhaustive):

- Inspect (or just glance at) an object either by jumping to a predefined viewpoint attached to that object, or by looking in the direction of that object from the user's current position. In the latter, a tracking mechanism should handle moving objects.
- Travel to an object following a logical path according to the metaphor in order to be aware of the objects relative positions or to monitor other objects along that path.
- Scan, traverse or visit several objects according to some criteria:
    - Scan all the objects that are children of a given object.
    - Traverse all the objects that have a common ancestor in the underlying hierarchy (depth first).
    - Visit all the objects from a user defined list or that the user has already inspected.

  This scanning requires jumping, travelling or looking at the successive objects.
- Have a global view of a set of objects. What is viewed from a parent is dependent upon the metaphor itself; the system may give an overview of all the children.
- Navigate in the 3D world relatively to the underlying hierarchy. The user can take advantage of his knowledge of the underlying hierarchical structure of the metaphoric virtual world.

4 Metaphor-aware navigation

One of the easiest ways to understand the idea behind metaphor aware navigation is to consider path-based navigation in a building. When a user wants to go from his current position to another office, he generally follows some logical path through the stairs and corridors (see Figure 1). Following this path (as opposed to instantaneous jumping) is important since it gives the user the knowledge of the relative location of the objects in the virtual space. Using traditional navigation tools, this kind of navigation is not an easy task. Metaphor-aware navigation will help him accomplish this task: the system will automatically route him along the right path in the building and will take care of the details of the navigation (e.g., turn, go down, and so on).

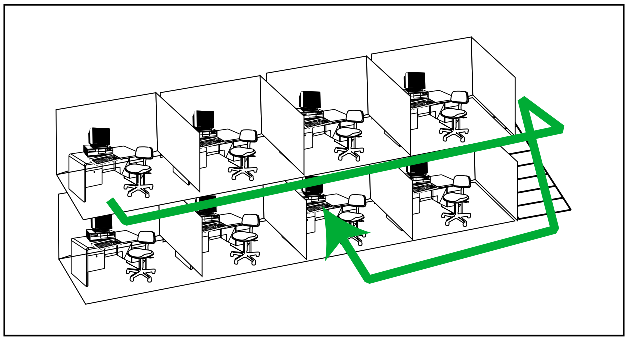
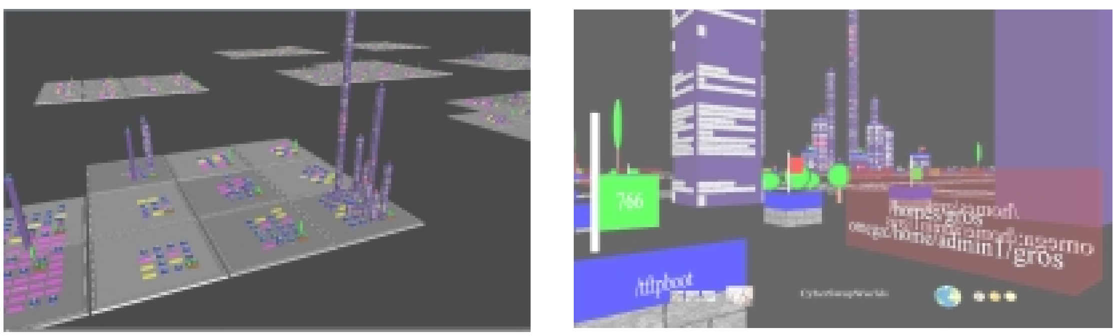


Figure 1: The metaphor-aware navigation path from one office to another.

Different navigation schemes may be used for navigating at different levels of the metaphoric world hierarchy. This kind of navigation is helpful to acquire survey knowledge. For instance, in a town, the user may navigate at the street level, walking in the streets in order to go from one building to another, or he may navigate at the district level, like a bird flying over the town (see Figure 2). The user will have a global view (seen from far away) when he is navigating at the district level and a narrowed, more local view when navigating at the street level.



Flying at the district level in a city metaphor

Walking at the street level in a city metaphor.

Figure 2: Adapt the navigation schemes to the hierarchy level (CyberNet project).

5 Navigation control

In order to assist the user in his navigation task, the system has to maintain the *user's current state*. The user's current state is constituted of three parameters: the *user's current location* in the 3D world, his *current node of interest* (the node that currently has his attention in the virtual world) and *a new node of interest*. The basic functionality of the navigation system is to allow the user to modify his current state (current location and node of interest) by specifying a navigation target.

5.1 Navigation target selection

Our metaphor aware navigation mechanism requires the user to specify a target for the navigation. The target is a metaphoric element of the virtual world and thus a node in the hierarchy that describes the world. This target is called the *next node of interest*.

Depending upon several other parameters described in the next section, the system will transport the user to this destination or it will orient the user to look at the destination. In CyberNet, the next node of interest can be defined using several basic mechanisms:

- ***Relative navigation*** requires the user to select the next node of interest relatively to the current node of interest. That is, the new node of interest is chosen relatively to the underlying metaphor hierarchy using traditional browsing operators such as up/down (in the hierarchy), or next/previous (element at that level).
- ***Navigating in the history buffer*** is very much like the "Back and Forward" provided by many html browsers. It allows the user to go back and forth in the previously visited nodes.
- ***Absolute navigation*** requires the user to select a new node of interest using absolute selection. This selection can be done either by using a 3D embedded interface (e.g., by clicking on an object in the virtual world), or by using an external menu that can be hierarchical and context sensitive.
- ***Automated trips*** may be defined by chaining destinations. This kind of mechanism only requires automating several of the previously defined basic mechanisms. Other navigation tasks such as inspecting all the nodes that are children of a given node also require automation. Automation involves getting to the next target (when several objects are involved) or back to the original location (when the end of the movement is reached). The automation requires the system to manage the time spent at each intermediate node of interest as well as the possibility to interrupt the navigation tasks (e.g., suspend, resume, stop).

5.2 Assisted movements

After a next node of interest is specified, the system will determine the set of movements that must be done within the context of the current metaphor in order to go from the user's current node of interest to the new node of interest. In our system, these movements are dependent upon the combined use of a *user mode* and a *movement mode*. The movement possibilities obtained by logically combining these two modes are explained in Table 1.

5.2.1 User mode: "Go to" / "Look at"

The user mode is used to indicate whether the user wants to move or to observe from his current location:

- In the **"*go to*"** mode, the user is transported from his current position to the next node of interest.
- In the **"*look at*"** mode, the user stays at his current location and his direction of view is modified in order to look in the direction of the next node of interest.

The precise movements are dependent on the movement mode described in the next section.

5.2.2 Movement mode: "Point to Point" / "Interpolated" / "Path"

In order to determine what should be done in order to "go to" or "look at" a target object, CyberNet supports three movement modes. The first two modes are derived from traditional 3D navigation tools while the third one is much more powerful:

- In the ***point to point*** mode, the user is tele-transported from his current position to the next very much like the viewpoint jump of many VRML browsers. Although we all dream of “tele-transportation” in our car every morning, this navigation scheme has some drawbacks. The user tends to lose his spatial knowledge of the world; he does not have information on the relative position of the objects anymore; and he cannot observe other objects along the path.
- In the ***interpolated mode*** the user’s position is interpolated from its original location to the location of the next node of interest. In the “fly to” mode, some VRML browsers support interpolation from the starting viewpoint to the destination viewpoint. The result is somewhat unpredictable as soon as the viewpoints have different directions of view (the user gets the impression of doing some strange looping). This is the reason why we implemented the *path mode*.
- In the ***path mode***, the user is transported along a logical path. Our main idea is that the path that should be followed to move from one node of the hierarchy to another relies on the metaphor itself and cannot be independently determined. For example, when a user wants to go from one office to another, he will automatically be routed through the corridor. If the office is located on a different floor, the corridor will have to route the user to the elevator (or stairs), the elevator will route the user to the desired floor and then to the desired corridor, and the latter will bring the user to the destination office.

Movement mode **User mode**	**Point to point**	**Interpolated**	**Path**
Go to	The user jumps to the new node of interest and gets attached to it. (VRML)	The user flies in a straight line from his current location to the new node of interest and his orientation is modified. (VRML)	The user travels from his current location to the new node of interest according to a metaphor-based path.
Look at	The user stays at his current position and looks in the direction of the new node of interest. If the object is moving then it is tracked.	The user stays at his current position, his direction of view is animated from its current value to the direction of the new node of interest.	The user stays at his current location, but his direction of view follows a metaphor-based path from the current node of interest to the new node of interest.

Table 1: Movements obtained by combining the different navigation modes (movements marked VRML are supported by most VRML browsers).

6 Implementation

6.1 The navigation wizard

A navigation wizard manages the CyberNet navigation system. The navigation mechanism requires the user to define a node of interest and a navigation mode. The role of the navigation wizard is:

- To manage the navigation user interface. This interface must allow the user to have access to both relative and absolute navigation. Relative navigation only requires the use of standard navigation buttons (such as up, down, next, previous).
- To always track the user's current location and current node of interest in relation to the metaphor hierarchy.
- To manage history and round-trip lists of points of interest in order to support automated navigation.
- To determine the path that must be followed and thus the set of movements that must be done within the context of the current metaphor and according to the current navigation mode. This is the most challenging part of the navigation wizard.

6.2 Metaphoric navigation components

In order to avoid complex centralised algorithms, the management of the path navigation algorithm exploits navigation information distributed in the nodes of the virtual world hierarchy. For this purpose, each node features a metaphoric navigation component. Upon creation each metaphoric navigation component notifies the wizard that it is a potential node of interest. In addition, for supporting metaphor aware navigation, each navigation component has three tasks:

- It provides a *neighbouring table* used to support relative navigation. The goal of this table is to be able to translate user action (e.g., up, down, next, previous) into a destination node according to the metaphor.
- It implements a built-in *routing table* very much like the one used by IP routers in order to route packets on the Internet. The goal of this table is to define which is the next node of the hierarchy that should be traversed to go from the current position to the desired destination. In the previous corridor example, going to an office on the next floor requires to go to some intermediate node like the elevator.
- It controls the navigation in the part of the space it has under its responsibility. In the previous corridor example, the corridor should effectively translate the user onto a path from one point to another. Of course, care should be taken during the design to insure that the path is continuous when moving from one node to the next.

6.3 The path navigation mechanism

The general path navigation mechanism uses the built-in mechanisms described above as follows: the routing tables are used as a mechanism to find the metaphoric route that links two nodes (see Figure 3). The navigation wizard follows that route and activates the traversed nodes along that route. Each activated node handles the effective movements. The current node first has to use its routing table in order to determine the next traversed node. When this node is identified, then the current node should animate the user's viewpoint from its current position to some position at the frontier of the next node. The path followed is dependent on the metaphor but is generally simple to implement because our basic graphical components have usually simple geometric characteristics. The complexity of the resulting world is an effect of the combination of a high number of simple components.

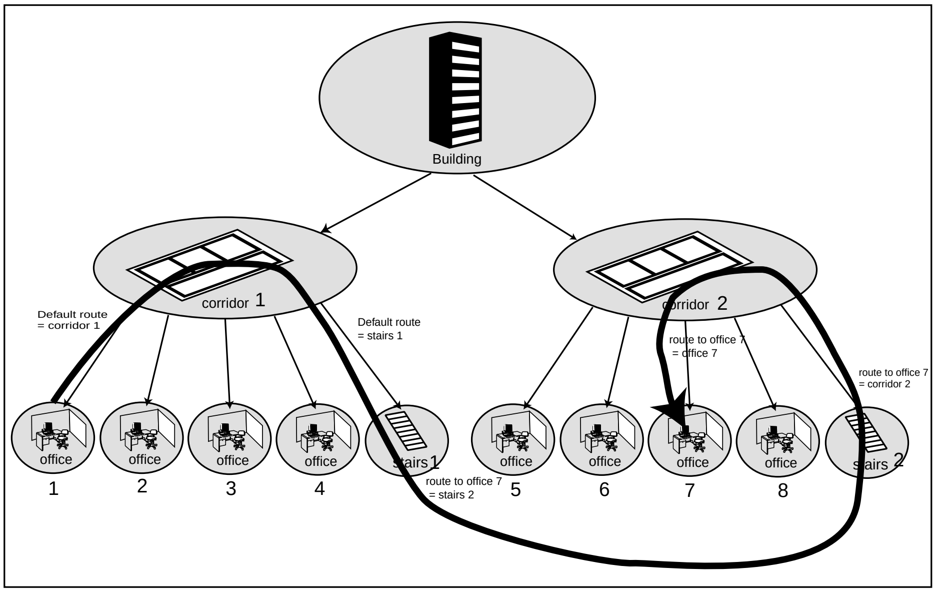


Figure 3: Path navigation mode - the metaphor hierarchy tree is traversed using routing tables.

It should be pointed out that the design of the metaphor-aware navigation is really part of the metaphor design. It has the same level of importance that the purely graphical/modelling work. An important point is to define a coherent navigation scheme for the metaphoric world as a whole. Thus, when designing a metaphoric navigation, the mechanisms to navigate in the world should be developed with the same care that is put on the pure 3D modelling (which involves the graphical design as well as the mapping between real world data values and visual parameters of the graphical components).

7 Metaphoric navigation example

As part of the CyberNet project we have developed a demo tool to visualize and inspect the physical location of network devices, according to their actual location in the Eurécom Institut building (Figure 4 and Figure 5). This demo also contains information regarding the personnel and the physical structure of the building, with the correct relative location of offices, labs and so on. You may access the online demos at CyberNet's webpage [13].

Although, at a first glance, it may seem like an exact three-dimensional reproduction of the actual building, the interaction possibilities with the virtual representation go way over than those of the real life building. The user may render any wall he desires transparent, may decide to hide/unhide information (for instance, rooms or entire departments) and may even change the whole configuration of the building by displaying a department per floor. Since the interaction capabilities do not constitute the scope of this paper we will not develop the subject further. Nonetheless, we must bear in mind that these kinds of changes also have a big impact on the navigation (e.g., when determining the navigation path that is to be followed).

The main reason for developing the virtual building demo was to test a first version of the navigation wizard and some of our ideas regarding the navigation in 3D virtual worlds. Mainly, we wanted to test the embedded aspect of the navigation, where the graphical components are responsible for handling the navigation in their "territory", and the selection of points of interest and the subsequent determination of the metaphoric path.

In the 2D interaction interface (that is visible on the left of Figures 4 and 5) the user may choose a destination point. The navigation mechanism then takes him there following the shortest "feasible" path (i.e., without traversing walls, taking the stairs whenever it is necessary to change floors, and so on). The selection menu is context sensitive (gives the current position as default for the departing point) and hierarchical.

Figure 4: CyberNet project – 3D visualisation tool of the Eurécom Institut building with visual information on the staff, machines and network infrastructure.

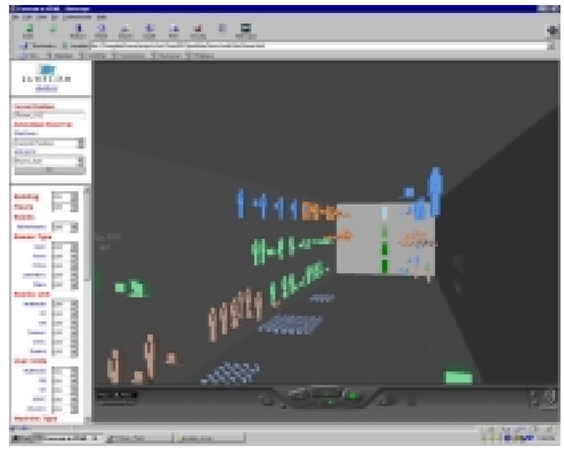


Figure 5: The Eurécom Institut building with transparent walls and floors, a suitable environment for testing the look-at navigation mode.

8 Conclusion and further work

In this paper we have presented the fundaments of the CyberNet project Navigation Wizard. Our major contribution is the metaphor-aware navigation concept, which is based on the principle that the way we navigate in a given virtual world depends on the characteristics of said world. In other words, the solution to an easier 3D navigation does not lie in one generic way of navigating that is applicable and appropriate for every single case. Furthermore, in the same world, navigation may also take different modes, depending on the hierarchical level of the metaphor in which the user is moving (e.g., flying at district level and walking at street level in a metaphoric city). The system assists the user in his navigation, it supports absolute/relative/history navigation control, and it provides different navigation modes and automated round-trips in order allow the user to navigate according to the task he has to accomplish.

In order to implement the automatic navigation mechanisms that follow those requirements, we have described how we embed the navigation capabilities in the virtual world hierarchy components. We have also described how we delegate the simple navigation tasks on the navigation components and make them responsible for all the navigation that must occur within their "turf" (usually defined by the graphical object's bounding box). We have shown how, based on the concept of neighbouring tables and routing tables, we are able to determine the metaphoric path that is the support of path-based navigation. And we have stated the role played by the navigation wizard, specially regarding keeping updated information on the user's state.

As further work we intend to enhance the navigation wizard to take into account some of the ideas that were already stated but have not yet been implemented. For instance, choosing multiple points of interest in a single step or implementing all the navigation modes (so far, for example in the demo presented above, only the path navigation mode is implemented). But the major test will be to implement the same navigation wizard in a dynamic world, i.e., a world that is updated on the fly to reflect the changes that occur in the network data. This poses several problems; for instance, what if an object that was selected as a new point of interest is moving or is deleted?

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