

# NAVIGATION IN VIRTUAL ENVIRONMENT

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## **Abstract**

*We present a method for automatic navigation inside a complex virtual scene, demonstrated on a large virtual model of the Department of Modern Art of the National Gallery in Prague. The basic navigation graph structure is constructed semi-automatically and it is subsequently locally changed by the exhibition editor which places new exhibition panels into the building interior and thus locally changes navigation route structure. The optimal navigation route is automatically generated using graph algorithms and user defined constraints.*

## **1. Introduction**

Virtual or augmented reality systems (VR) are natural way how to visualize, manipulate and interact with complex digitized information about real world objects in a simple human way. Recent progress in computer technology, range cameras and the corresponding computer graphics and computer vision methods enables to build ever-growing number of more and more complex VR scenes in various application areas such as 3D games, military or civilian training simulators, architectural models, archeological applications, World Wide Web, digitized cultural heritage sites, etc. These advances in technology allow the shift from text oriented information systems to full 3D graphical ones.

Distributed virtual reality information system vastly improves access of citizens, disadvantaged people, or professionals to culture knowledge bases collected in museums or galleries. Many cultural heritage monuments endangered by crowds of visitors or even already closed for public can be accessed through their virtual models. Other monuments stolen, damaged, moved from their natural environment (e.g. Elgin's marbles, Codex Gigas, etc.) can be completed with their original setup. Restoration plans, exhibition planning, manipulating of fragile physical objects, environment changes and many other cultural heritage maintenance problem can be cheaply and safely solved in simulated virtual information systems. Finally some cultural heritage can be preserved only in digital form due to natural disasters or human ignorance. Another obvious application is virtual information and simulation systems for environments too dangerous, hostile, or even inaccessible for humans such as radiation contaminated environment, body interior for microsurgery treatment, etc.

3D graphical communication and presentation creates natural environment for users because such virtual reality information environment simulates natural surrounding for human beings in which people are accustomed to orient themselves. Single objects are presented in their mutual contextual relations in the simulated realistic time-spatial space and hence offers far richer information than the usual textual, still image or multimedia databases. VR environment can not only approximate some real world experience but it can provide unique experiences which are either impractical, dangerous or utterly impossible to achieve in real world. Serious problem is the user friendliness of the user interface of a 3D browser. Effective use of this interface requires some experience from the user what

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**Figure 1. National Gallery in Prague virtual model.**

is not always the case.

A solution to this problem is automatic path generation that defines a trajectory of the virtual walk through. The parameters of the path (starting point, end point, usage of a staircase etc.) are defined by the user. This solution helps us to solve another critical problem: the performance of a computer to be high enough to generate the virtual walk through in real time. Even experienced user will appreciate reduction in user's fatigue because in most of the existing VR systems, the user has to input the moving event with a mouse or keyboard continuously if he wants to travel in the virtual environment.

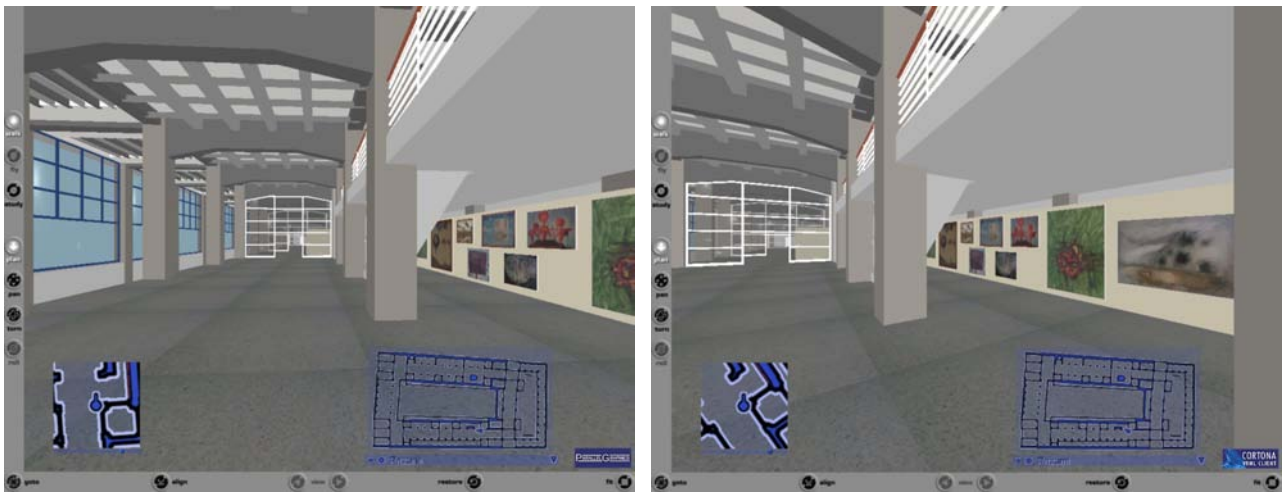
While navigation in real world, i.e. traveling to a specific target location, is often a challenging and not completely understood problem [3], especially in unknown environment (e.g. city, forest, sea) and many support tools were developed from simple compass to sophisticated GPS (Global Positioning System) based navigators, navigation in VR environment [1, 2, 10, 11, 12, 13, 14] is even more difficult due to many missing real world cues. A major problem for users of virtual environments is maintaining knowledge of their location and orientation while they move through the space because perceptual judgements are biased within a virtual environment. Several tests have shown that users wearing a head mounted display for example underestimate dimensions of space, which might be caused by limited field of view. Several solutions to selected virtual navigation problems were published, e.g. constant navigation velocity [11], collision avoidance, path adjustment, gender factor support [15] or navigation support tools [3] but this problem is still not satisfactorily solved.

The proposed solution for navigation in complex virtual information system is demonstrated on the complex model Fig.1 of the Department of Modern Art of the National Gallery in Prague. In order to test the navigation algorithm on real data we created accurate and realistic virtual model of this huge gallery building. The gallery has seven exhibition floors and two large exhibition halls in the ground floor. All seven floors of the gallery building interior can be automatically navigated using the method detailed in the following sections.

## **2. Actual Position Visualization**

Actual position in a complex virtual scene is depicted as the highlighted point in an overlaid transparent map and its local detail (left overlaid map) or building floor plan Fig.2. The map window can be moved by mouse to any appropriate screen location and the detailed map can be scaled. This point is continuously moving as the user or an avatar moves in the virtual scene and the map detail is rotating according to the view angle (compare both maps in Fig.2). If we leave a building floor for another one, the floor plan is switched accordingly to the actual one. Each plan is labeled with the

corresponding floor number or label (i.e. ground floor - Přízemí).



**Figure 2. Current position visualization.**

### **3. Preset Routes**

Manual creation of virtual reality models of real world scenes and navigation routes inside them is tedious and error-prone work as the scene complexity increases and automation may substantially reduce the laboriousness of the whole process. Possible routes are determined to large extent by the building designed and this information can be exploited for possible navigation network setting if we are prepared to compromise full generality of possible routes. For example we assume that a visitor will never walk closer than half meter from the walls, enter each exit in its center, larger spaces are covered with walking loops with minimal diameter one meter, etc. Each floor plan is then supplemented with a preset routes graph structure given by the basic building structure. Single corridors, lifts, staircases are represented as graph edges, while doors, branchings or turning points are graph vertices. This prior graph structure which represents initialization of navigation routes can be generated semi-automatically based on the floor plans. Narrow corridors have single graph edges while wider corridors or halls can have even several graph loops (see Fig.3-left loop booked in the middle hall). This automatically proposed graph structure (primary graph) can be interactively edited using the exhibition editor described in the following section. Superfluous edges or vertices can be removed while new edges and vertices can be added. Single edges or vertices can be also shifted to other positions. Vertices can be also supplemented with additional attributes such as emergency exit, lift, staircase, door, etc.

### **4. Exhibition Editor**

Our Virtual National Gallery allows to interactively build virtual exhibitions using our exhibition editor Fig.4. This editor was devised for the National Gallery exhibition architects to support and speed up their exhibitions proposals. The editor loads requested floor plan and allows to insert single exhibition panels Fig.4-right and to specify their parameters such as single dimensions, colour, covering material, etc. Single paintings from the gallery are subsequently set out on these exhibition panels and other supplementary data can be attached e.g. information about a painter in the corresponding pop-up window. When the exhibition editing is ready, it is exported into the VRML building model

and can be immediately checked in the browser. However, these newly inserted panels (Fig.3-middle) change the corresponding part of the underlying navigation graph. The first step is automatic generation of a subgraph around these new panels Fig.3-right. This new subgraph is inserted into the preset primary graph with higher priority than has the corresponding primary subgraph. The primary graph edges and vertices which are overlaid by this new subgraph are temporarily disabled (Fig.5-right dash-and-dot brown edge). If the subgraph does not overlay any part of the primary graph (e.g. a new exhibition in the previously empty hall far from default primary graph hall paths) it is automatically connected to the nearest primary graph vertices. When the exhibition is later changed or removed the primary subgraph can be restored to its original shape (Fig.5-left).

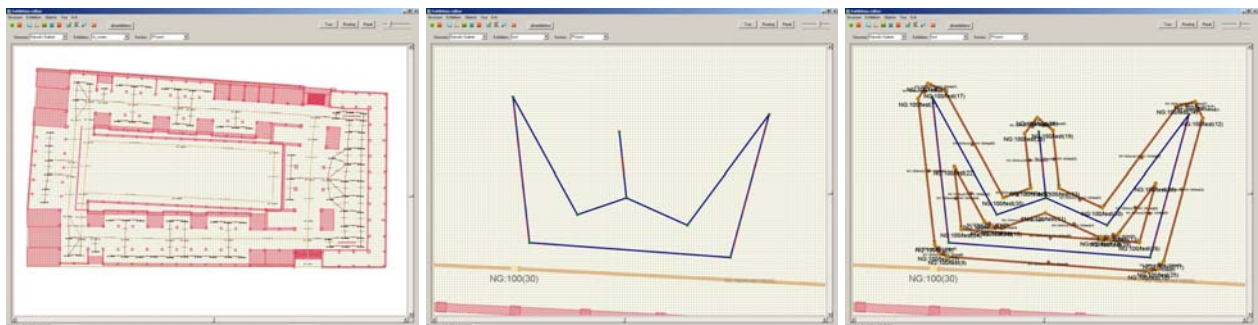
## 5. Optimal Path Search

The solution to this problem is to generate a sort of movie that represents the virtual walk-through in the scene. Such a movie can be played forwards and backwards thus providing necessary information about every part of the trajectory the user goes virtually through. Generation of a path from parameters given by the user is done automatically in a module that considers the ground plan of a 3D scene as a labeled graph. The labels represent various kind of information like accessibility of some location from the point of view of handicapped persons etc. Single edge attribute is also its physical length, thus it is possible to estimate real time needed to walk a specified route in real National Gallery Prague palace as well as time needed for an exhibition sightseeing tour.

The process of the path finding is in principle finding the optimal path in a given graph. Motion planning has been studied for several decades and many motion planning algorithms were published, however VR path planing is simpler than robot motion planning [9] in unknown dynamic environment and simple graph path methods cab be used.

The shortest path is found using the Dijkstra algorithm [4] and it represents the required navigation route through the gallery building where we assume only static obstacles and environment changes restricted to the exhibition editor. Such request can be emergency evacuation assessment, route for handicapped visitors, educative thematic route, time limited gallery visit proposal or simply visitor's information support.

This navigation route is subsequently used for generation of a movie that represents the virtual walk-through. This walkthrough can be demonstrated using avatars Fig.6 or simulating eye view of a visitor Fig.7. The user interface has only few features. They do not require some specific knowledge (for-



**Figure 3. Generated gallery ground floor preset routes (left), user generated exhibition panels floor plan (middle) and the corresponding automatically generated navigation subgraph for this exhibition (right).**

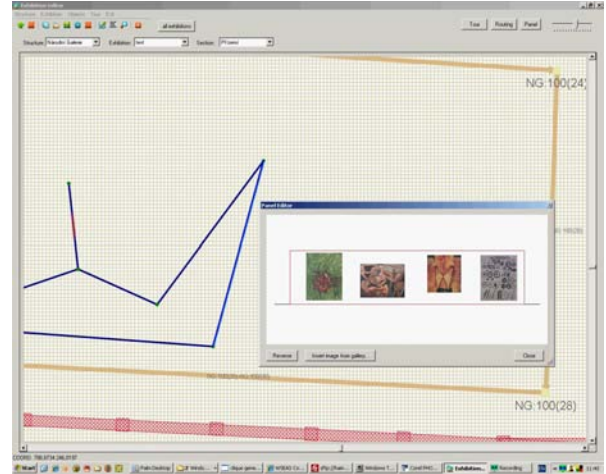
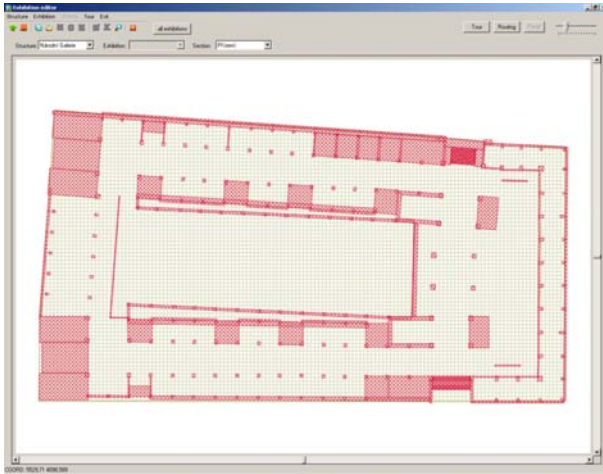


Figure 4. Exhibition editor with floor map and single panel editor window (right).

ward, backward, stop etc.). This fact allows the use of the navigational system even for novice users. A visitor can watch not only animated thematic visit to his or her selected artistic subjects, possible from home over internet, but also print a map with the proposed personalized route.

## 6. Experimental Results

Virtual National Gallery in Prague Department of Modern Art model was partly automatically acquired using our setup for automatic acquisition of virtual reality models using laser scanner Konica Minolta Vivid 9i and our modeling software. All parts of this system [7, 8] are fully functional and were tested with satisfactory results on gallery small real objects. Unfortunately, this range camera is not capable to measure large building structures and thus we were not able to acquire range data from the gallery building itself. Single architectural shapes in the model were created instead using building blueprints and acquired photographs. Virtual reality systems require object surfaces covered with realistic nature-like colour textures to enhance realism in virtual scenes. The model surface materials are represented by synthetic textures generated using our multiscale Markov ran-

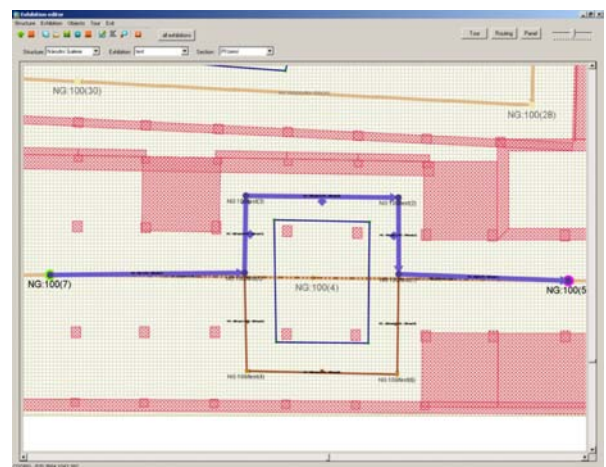
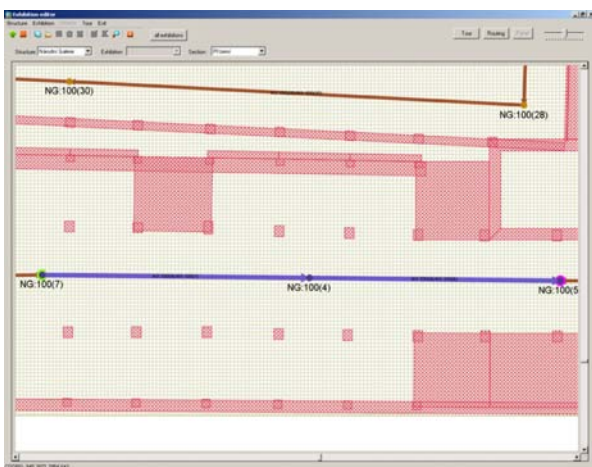


Figure 5. Navigation route detail (left - blue edge) and its modification by the editor (right).



**Figure 6. Animated navigation route using avatars.**

dom field based methods [5, 6]. The texture Markov random field based model consists of a set of Gaussian Markov random field submodels for single orthogonal mono-spectral single-resolution texture factors. Parameters of the Markov random field submodels are estimated and subsequently used for given factors synthesis. Resulting synthetic colour texture is composed from these mono-spectral single-resolution factors after corresponding inverse transformations. Although these colour texture models are slightly spectrally compromised due to this spectral decorrelation transformation, the appearance of colour synthetic textures in the gallery model is very good and nearly visually indiscernible from their natural counterparts.

Figs.1,2,6,7 show different images from the Virtual National Gallery model. The gallery model is created in the VRML2 language. Single building floors are separated VRML scenes which are automatically loaded whenever avatars or users are moving from one scene into another using, for example, virtual lifts or model staircases.

Fig.7 presents selected eight frames from the automatically generated route to reach a newly installed small exhibition on three panels. The given task was to find shortest route from gallery entry to the selected exhibition part (three panels with eight paintings) for a regular visitor, survey these paintings and return to the exit. The system found automatically the correct route, its length in meters, estimated sightseeing time and animated this tour in the realistic setting of the virtual gallery model. It is also possible to print the floor plan with the highlighted suggested route. If we require disabled person (or wheel chair) constraint, the generated route will avoid staircase (Fig.7 top row leftmost image) for the lift with slightly longer route.

## **7. Conclusion**

The proposed solution for the virtual information system construction is demonstrated on the model of the Department of Modern Art of the National Gallery. This collection of images, drawings and statues from the period of 20th century is located in a functionalistic building in Prague. In order to test the navigation algorithm on real data we modeled manually and semi-automatically the interior and exterior of the whole gallery palace. Automatic acquisition of virtual models from registered range and colour real image data and automatic generation of navigation routes in the virtual scene is possible combining novel efficient and robust methods indicated in the article. Very complex scenes with large non-planar faced objects, still require human feedback and corrections. However even in this case the model acquisition procedure significantly simplifies a virtual model building task.

Although recent technological advances already enable automatic or at least semi-automatic construc-

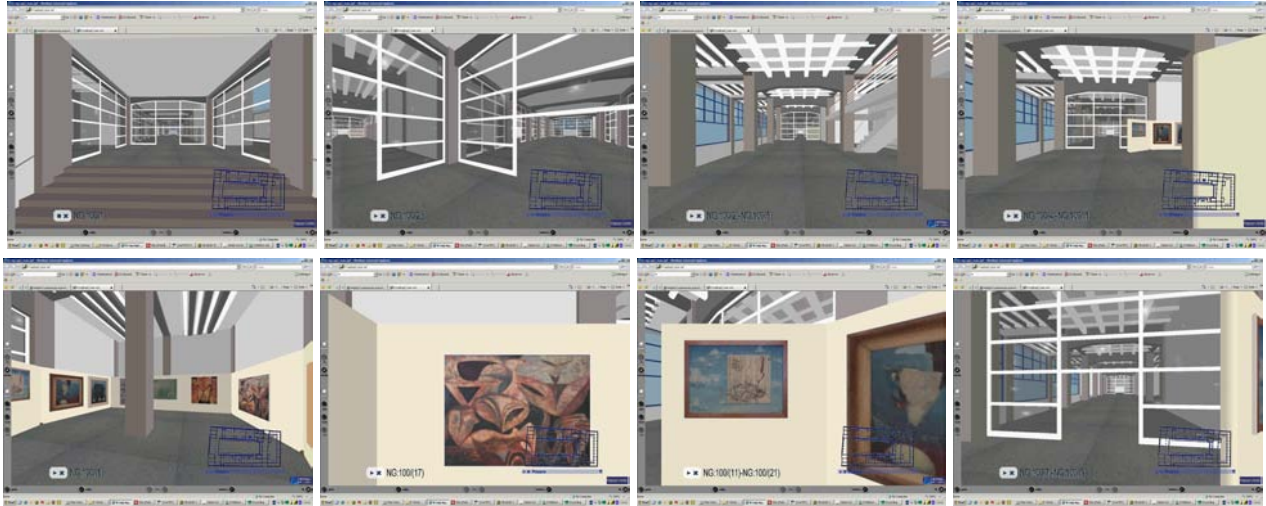


Figure 7. Navigation frames (0,5,10,24 top, 26,32,39,43 bottom).

tion of complex distributed virtual models, further research is still needed to enhance physical look and feel of resulting models together with their performance and storage requirements. The VRML2 language has many functional restrictions for example missing support for the most advanced material representation - the bidirectional texture function and some better distributed virtual reality modeling language is clearly required. Current state-of-art of image analysis has its limitations as well in reliable image and range segmentation of complex or inhomogeneously lighted scenes.

### 7.1. Acknowledgements

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