Examination of users' routes in virtual environments

C Rigó and C Sik Lányi

Virtual Environments and Imaging Technologies Laboratory, University of Pannonia
Egyetem u. 10, Veszprém, H-8200, HUNGARY

csabarigo@freemail.hu, *lanyi@almos.uni-pannon.hu*

ABSTRACT

We developed 3 virtual environments (VEs): a VR gallery, a VR store and a VR labyrinth for the investigation of the users' routes in these VEs. In this article we examine the matching of these tours with two developed utilities. From the results we want to draw the inference to the practical development of the virtual environments for defined groups of users. We examined left-handed, right-handed persons and people who play often with VR games as well as people who play with VR games rarely or never. The VE and the developed testing frame software are adaptable for every disabled group's route examination.

1. INTRODUCTION

Nowadays virtual and 3D-workspaces are highly relevant at the development of graphical user interfaces (GUI). 3D menus, 3D-task switching are already services of the operating systems, although these are not virtual environments. These GUIs display depth only with shading and texturing. The advanced version of these GUIs is the 3D-workspace, where the 2D objects are displayed in perspective view. If a graphical object is far from the user, it takes less space on the display, and if it's pointed, the user gets closer to it, and it will be bigger on the screen. Hereby the 3D-workspace gives more space and comfortable navigation. Its improved version is the virtual reality, which is the most sophisticated method of information visualization, but special display devices (for example: head mounted displays) are needed to use this method, so that the user can move in a simulated 3D world. This is the most advanced form of the dialogue between the user and the computer. This kind of GUI makes a quick interaction possible, because the user gives continuous instructions and gets feedback from the computer.

If we want to develop usable, user friendly virtual environments, we have to know, how the users tour about them, to be able to set the priority between the functions of the system, which we develop. Therefore our primary goal was to investigate the users' routes. The developed testing frame software is usable for every disabled group's route examination.

Bagyal developed labyrinths to test the routes between left- and right-handed users in his thesis. He concluded that there is a significant difference in the navigation of users in virtual environments, caused by the handedness. (Bagyal, 2004) That is why we decided to divide our testers in left- and right-handed groups.

Tilinger investigated the same task with a fire-alarm- and a labyrinth simulation, complemented with the differences of the perception of information caused by handedness. He found no significant difference in the information-perception and he found only a slight difference in the behaviour in virtual environments of these groups (Tilinger, 2006).

Matrai created an algorithm to investigate the users' navigation on web pages. It shows the significant orders and places of the clicks of the users. (Mátrai, 2008) It can be applied for our goal, to determine the important route by the examination of the users' routes, in a VE. Based on above we wanted to investigate the navigation routs in more detail, to be able to provide best practise for every type of disability.

2. DEVELOPING

A test application was used during the examination of the routes, which contains three virtual environments: a gallery, a labyrinth and a store.

The virtual environments of the testing application were developed with Alias Maya 7.0. This software hasn't got a feature for interactivity, that's why a 3D-engine was needed, with which the frame-program was developed. The Irrlicht3D is an open source engine, which has a GUI library too. It was written in C++, but it's programmable in most of the common languages (C++, C#, Java, Delphi), C++ was used during the development. The application has two tasks, to test and save the users' routes, and to evaluate them. That is why two modules have been developed. The tester module has a form, which asks the user's name, group and the VE. After clicking the start button, the test begins (Figures 1, 2, 3). Between the Maya and the Irrlicht3D the Object file format gave the compatibility. These files were imported into the IrrEdit, a utility of the Irrlicht3D, which gave a render feature for the environments, so with lights they became more realistic. The movements of the testers were exported into XML files, which can be used trough an import method by an evaluating program. The XML files were saved automatically.

The evaluating application was also developed in C++, using the GUI library of the Irrlicht3D. It also has a form, in which the evaluating person collects the routes into a file list, wherefrom the program reads and evaluates them. There are two ways to evaluate them. We developed an algorithm, which evaluates the differences between the routes and this algorithm characterises the evaluation with a Gini-index. The other one is Matrai's algorithm, used to determine the most significant route. The results are displayed in an XML file, for the further evaluations.

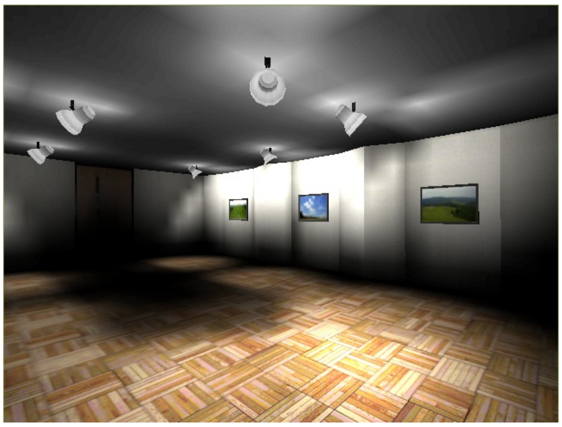

Figure 1. *View of the gallery.*

Figure 2. *View of the store.*

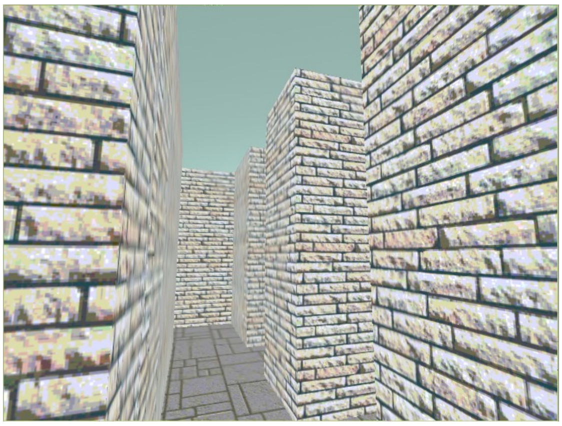

Figure 3. *View of the labyrinth.*

3. TEST ENVIRONMENTS

The virtual spaces were chosen to be simple environments of the tester's tasks. A gallery, a store and a labyrinth are good scenes for an easy, objective evaluation, where the routes can be noted. The task of the test-persons was to look at the objects of the gallery and of the store, as well as to find the exit of the labyrinth. These routes are only horizontal, there's no way to walk in the environment in height. The environments are developed to be symmetric, not to influence the testers in their movements (but the observer does not know that the VE is symmetric), and the viewable objects shall arouse their interests in an equal rate, too. The spaces are selectable for each examination; it's not necessary to use all of them at one occasion. All three VEs have the same floor-space, so the examination of the coordinates can be easily carried out. These coordinates are given by a grid, which can be set by a configuration file. If a point of the grid is touched by the tester, it will be noted in the structure of the going, so the path can be saved in a file at the end of the examination.

The task in the gallery (Figure 1) is to view 8 pictures in an arbitrary sequence. This environment gives a free space; no barriers are placed against the tester. In the store (Figure 2) a shelf was placed in the middle, so the space can only be walked in a circle from the left to the right or in the opposite direction. If the grid is smooth enough it's also possible to examine whether the path leads on the inner or outer side of the circle.

The task of the third space is to get out of the labyrinth (Figure 3). Although it's symmetric, it's possible to walk through it using two corridors, so the exit can be found in several ways.

4. EXAMINATIONS

The test users were divided in four groups, left-handed (9 persons), right-handed (7 persons), experienced (11 persons) and novice (5 persons) users of the VR applications. Most of the users were young and almost all of them were experienced in VR use. Because of the low participation, only a pilot-test was conducted. At the execution of the tests, the help of the examination leader was needed, because the application had to be introduced to the novice users. The experienced users accomplished the test on their own, trough the internet. The application was posted as an attachment of an e-mail, and they sent the results back the same way.

The examinations were evaluated in two ways. The first method compares the couples of the routes' in one group and uses the Gini-index for characterization of the differences of their comparison. The second method uses Mátrai's algorithm for this task (Mátrai, 2008). It shows the most probable route in the virtual environment on the base of the tested routes. This algorithm gives an adjacency matrix, which can be evaluated manually and with a MathLab function.

At the beginning of the wandering, the VE is divided, and during the tour, the coordinates of those places are stored, which were wandered by the tester. Every route is stored as a sequence of coordinates. The edges of the routes are calculated from these coordinates. The routes, represented by the edges between the coordinates, are compared in couples. If an edge is present in both of the routes, an edge count will be incremented. This computation gives the following two quotients (Eq. 1), that contains the collective edge count and the number of the edges on each route. These quotients aren't equivalent and both of them will be stored, so the computation doesn't need to be run twice with the same routes.

The quotients of the compared routes are

$$y_{12} = \frac{\text{common edge count}}{\text{edge number of the first route}}; \qquad y_{21} = \frac{\text{common edge count}}{\text{edge number of the second route}} \tag{1}$$

As we examine the difference between the routes, we use the following differential quotients:

$$d_{21} = 1 - y_{21}; \qquad d_{12} = 1 - y_{12}; \tag{2}$$

The algorithm compares every route to very other route. Two embedded loops are defined in the code and the inner loop starts from the actual value of the outer one. With this method a computation won't run twice, with the same routes.

At the end of comparing the loops, the dispersion of the stored quotients will be characterized with the Gini coefficient, the formula for which is given as

$$G = \frac{\sum_{i=1}^{n}\sum_{j=1}^{n} d_{ij}}{n(n-1)}; i \neq j \tag{3}$$

The second way to evaluate the routes is Matrai's algorithm. It also uses the edges of the routes during the evaluation and represents an adjacency matrix, in size of the VE's divisions. The rows and columns of the matrix will be the vertices of the route. In the beginning, all the values of the matrix are 0. As the algorithm iterates through the routes, at the starting and finishing vertices of the edges, the current value of the matrix will be incremented. When the iteration finished, all of the values of the matrix will be divided by the sum of the rows. With this step, the outgoing edges' values will be between 0 and 1, that's why we call this route the most probable route, and it shows the significant route of the VE. To determine this route, we have to make the matrix negative, and use a shortest path algorithm, which works with negative values too.

5. RESULTS

In the present experiment we examined only left handedness and right handedness, as well as the two groups of users, who used VEs often and who were novice users. This was, however only a pilot study, and it can be extended for the examination of any other study group, e.g. for the comparison of intellectually disabled persons with average users or users who have difficulties in learning, etc. The present results concentrate on the investigation of handedness.

We had only 16 routes from the examinations, which is not enough to make stable conclusions, but these examinations gave interesting results, witch should be examined with a bigger tester base.

At the evaluation of routes in the labyrinth, the most probable routes lead right from the starting point, (Figure 4) and most of them cross the labyrinth. This result is relevant in all of the examined groups.

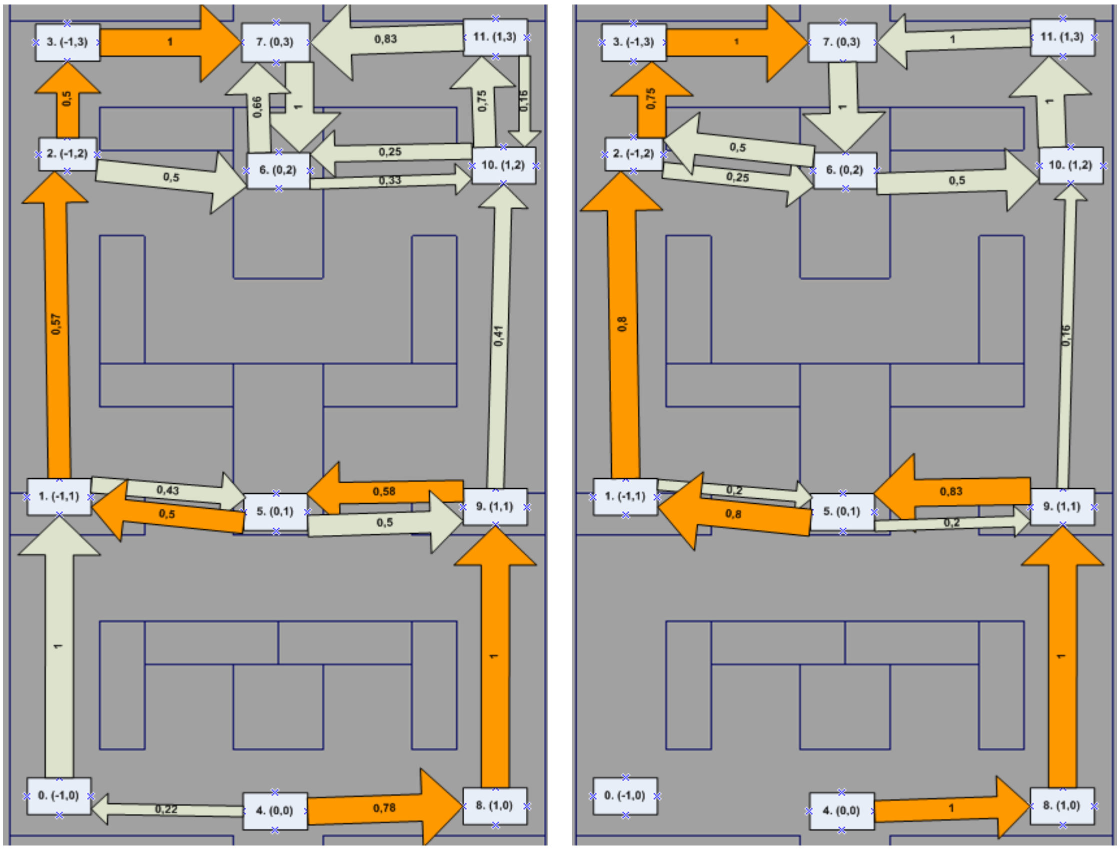

Figure 4: *Most probable routes in the VE Labyrinth. Significant routes are marked with yellow.*

At the evaluation of the routes by handedness, most of the testers watched the pictures of the VE Gallery in a circle, although this environment is free to wander (Figure 5). The left-handed users wandered it from left to right, and the right handed users from right to left.

These results are confirmed by the probable routes of the VE Store, where the left-handed users wandered from left to right. For the right-handed users it is equalized between the two directions (Figure 6). To conclude these results, we need a bigger tester base.

Evaluating the routes by the novice and experienced groups, we found that the significant routes in the store and gallery are almost equally divided between the two groups (Figure 7). Only the labyrinth shows divergence, because the experienced users discovered the labyrinth.

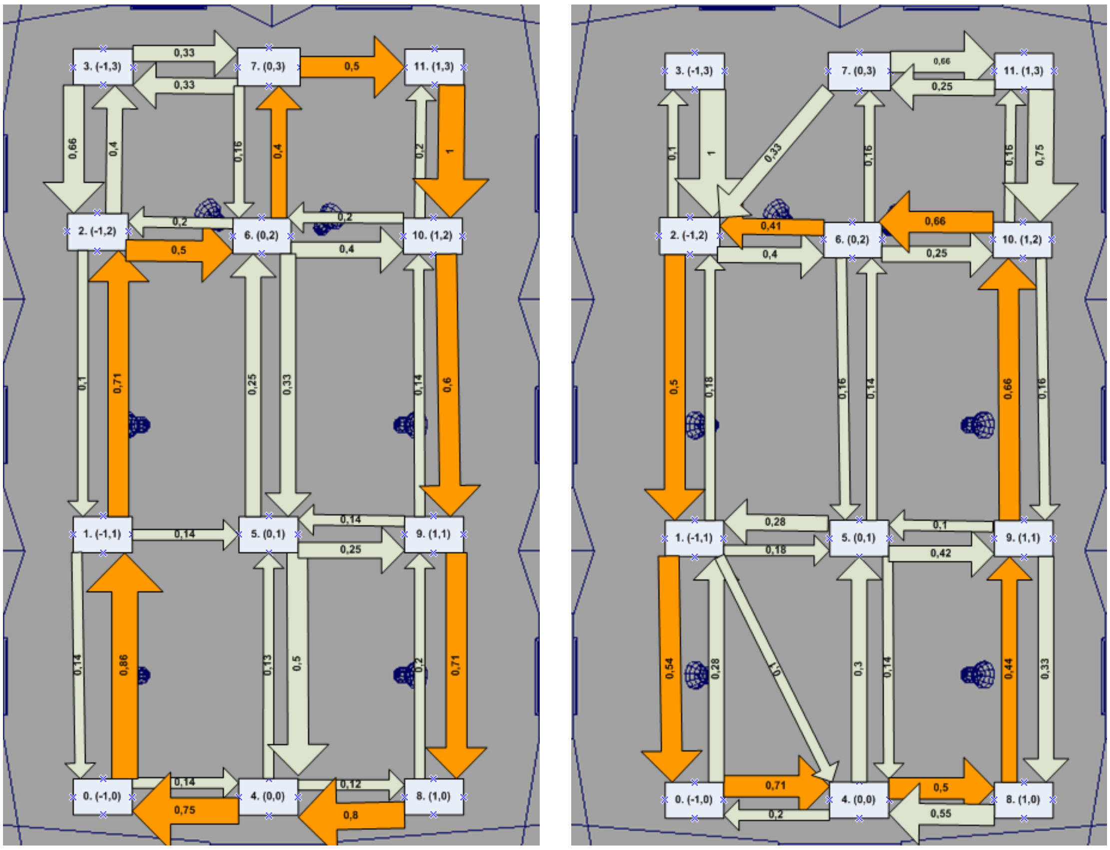

Figure 5: *Most probable routes in the VE Gallery.*
Significant routes are marked with yellow.

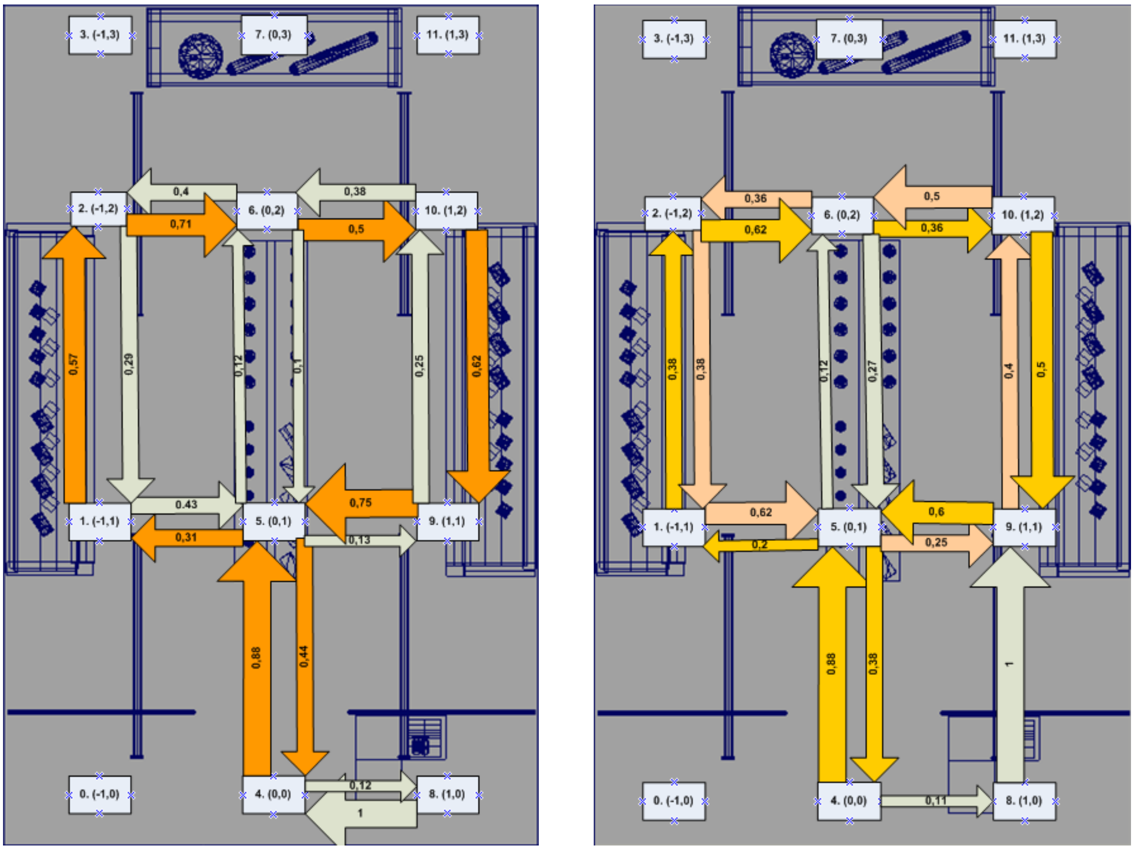

Figure 6: *Most probable routes in the VE Store.*
Significant routes are marked with yellow.

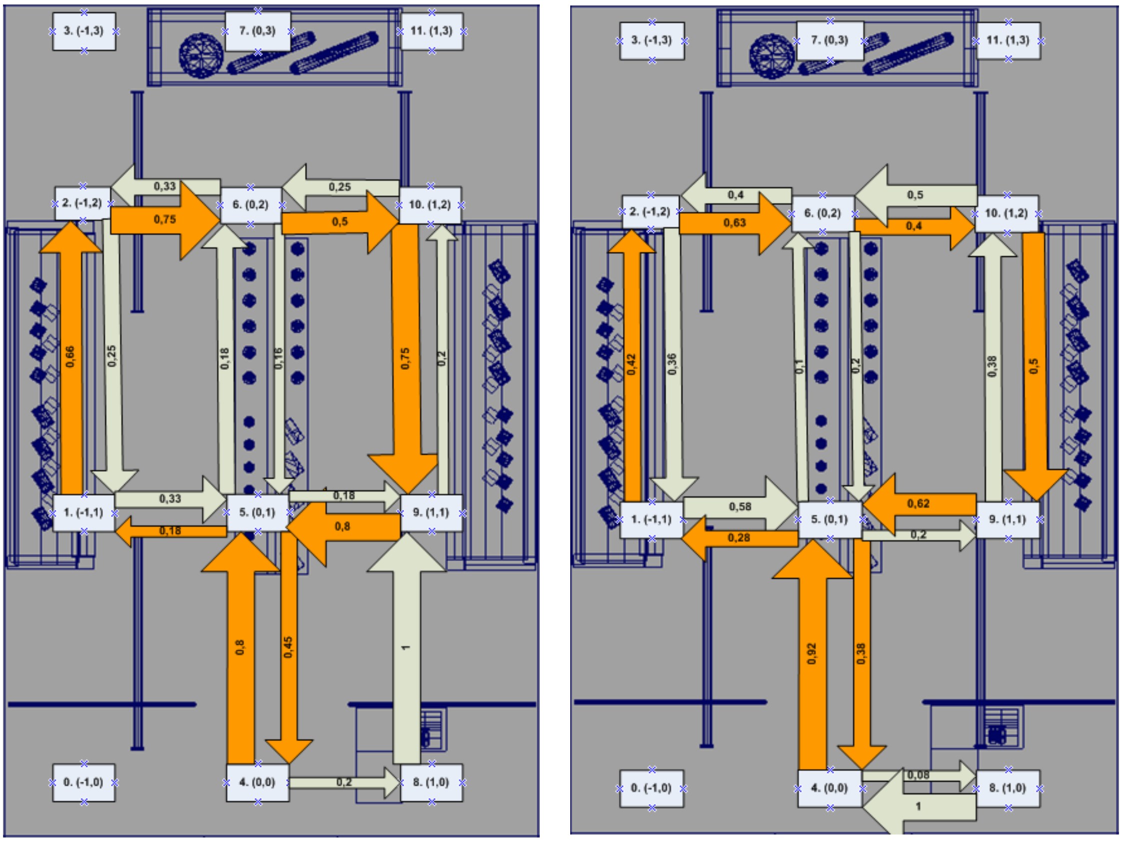

Figure 7. *Most probable routes in the VE Store between the novice and experienced groups. Significant routes are marked with yellow.*

6. SUMMARY

Three virtual environments (VE): a VR gallery, a VR store and a VR labyrinth were developed for the investigation of the users' routes. 16 observers used this test software in 4 groups: left-handed, right-handed, people who play often with VR games and people who play with VR games rarely or never. The result of the pilot test is positive, we found difference between the left and right handed users' routes, but more data are needed to prove this conception.

7. REFERENCES

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