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USER TESTING WITH TOOLS FOR 3D VISUAL NAVIGATION

SCHMIDT M.A.R.(1), DELAZARI L.S.(2)

(1) Instituto Federal do Triângulo Mineiro, UBERLÂNDIA-MG, BRAZIL ; (2) Universidade Federal do Paraná, CURITIBA, BRAZIL

ABSTRACT

The use of cartographic representations in three-dimensional views gathers the advantages of technological advances for handling and storage of spatial data. However, the cartographic knowledge needed to build these representations have not been developed in the same way as technological change. As a consequence, there are not general principles of map design for 3D maps and, usually, misconceptions can be found on maps that restrain or even impair the understanding of represented features and their spatial relations. A common task in 3D map-use is the virtual navigation, which is performed with three-dimensional topographical maps. Navigation can be defined as the process whereby someone determines their position and orientation related to other elements of landscape and uses this knowledge to move to other locations. However, determination of relative orientation is not a trivial task on virtual environments. This problem is aggravated by the lack of knowledge of how users react to the new perspective and perceptive differences proposed by it. There's a need of adaptation of these representations to 3D. A few navigation assistance tools have been proposed in literature, normally based on analogies of electronic tools used to navigate in real environments. This paper evaluates the influence of some of these tools in accomplishing tasks of navigation and orientation done by map users and identifies which features are used for doing it. To reach this goal, we developed a testing methodology which combines qualitative think-aloud protocol and evaluation by questionnaires. This paper presents the preliminary results of this research and the low cost procedure used to identify the elements of representation used as references.

1. INTRODUCTION

This paper presents the results of using some virtual tools developed to assist users of topographic maps to navigate in 3D non-immersive virtual environments comparatively to landmarks. In this system, the visualization of three-dimensional scenes is performed by monitors, keeping users out of scene. In non-immersive virtual reality (VR), the representations are created by a software able to read input data and to create a perspective image on screen. The use and dynamism of 3D maps are empowered by the ability of manipulation and data storage of computers associated with interactivity and change of viewpoint, which are fundamental to create a sense of virtual reality. However, the cartographic knowledge needed to build these representations has not developed the same way that technological development has. As a consequence, there are not general principles of map design to create 3D maps and there are misconceptions on maps that restrain or even impair understanding of the represented features and their spatial relations.

The construction of 3D representations and its impact on users have been discussed in literature by several authors in recent years, especially on geographical use-task as virtual navigation in 3D topographical maps. Examples of those pieces of research are Vinson (1999), Darken and Paterson (2001), Haeberling (2002), Tory et al (2004), Harrower and Shessley (2005), Haeberling et al (2008), among others. However, determining relative orientation is not a trivial task on virtual environments and some navigation tools have been proposed in literature, usually based on analogies of electronic tools used to navigate in real environments. This paper evaluates the influence of some of these tools in accomplishing tasks of navigation by map users through the identification of which features are used as landmarks and their characteristics. To reach this goal, we have developed a testing methodology which combines qualitative think-aloud protocol and evaluation questionnaires. The result is a low cost procedure, which is effective to identify the elements of representation used as references.

2. BACKGROUND

Navigation is defined by Darken and Peterson (2001) as a process which combines orientation and movement used by people to determine their relative position and relative position of other elements on the landscape, as a way to reach other places from a certain position.

The authors believe the sense of orientation is the cognitive portion of navigation, without considering any type of movement but tactical and strategic decisions that lead the movement. These authors also point out that the essence of the sense of direction is the development and use of cognitive maps or mental maps as a decision making support tool. To navigate successfully, people must plan their movements using acquired spatial knowledge about the environment and knowledge stored in a mental map that represents the area. This type of navigation can be performed by memory with a series of associations between landmarks and their corresponding acts of navigation. For example, "turn right by the church" (Vinson, 1999). To create cognitive maps, users rely on three distinct types of spatial knowledge: knowledge of landmarks, knowledge of routes and ground knowledge (Werner et al, 1997).

The knowledge of points of reference is the most basic knowledge form of environment. These points are distinct characteristics of the environment that stand out from other pieces of information and spatial objects around them. They perform different functions in the organization of directions and routes to determine points used to evaluate progress along a route or to provide an overall direction (Werner et al, 1997). The reference points act as anchor points from which users organize other pieces of spatial information in a representation (Vinson, 1999). In the perspective view of 3D maps, users can experience difficulty in recognizing and identifying reference points. This can lead users to feel disoriented and the process of acquiring knowledge of the area may be damaged. The main problems with navigation in 3D maps pointed by Harrower and Sheesley (2005) are:

a) Limitations of oblique perspective: the perspective effect caused by the variation of scale through the scene from the viewpoint of the observer and across the sight line turns determination of distance and direction of areas into a difficult task. Many tasks in which use of representations is required, easily performed in maps, become a challenge on perspective view, such as defining which route is longer (Harrower and Sheesley, 2005).

b) Excess of information: reasons for application of cartographic generalization in maps are the same for 3D maps – to reduce levels of details and to expose relationships and spatial patterns. The effect is similar because users are allowed to organize space and landscape structure in their mental maps with higher efficiency.

c) Visual occlusion: during the observation of a surface view, portions of this surface may be occluded due to a viewing angle or height variations of relief. The survey of Tory et al. (2004), related to the passage of pedestrians in urban areas, revealed that simultaneous use of top view (2D) and perspective view (3D) is significantly more efficient than visualizing each one of them separately for guidance;

d) Disorientation: disorientation is the greatest cognitive challenge for users of virtual environments (Harrower and Sheesley, 2005), because the biggest problem seems to be how to allow users to keep oriented. One strategy to counter attack the confusion is to use navigation virtual tools built from metaphors to guide users. The term metaphor for guidance is understood in this paper as an analogy of navigation devices from which virtual tools are built. For example, the determination of azimuth can be achieved by the metaphor of a compass placed at the interface of the virtual 3D map. The metaphors or tools selected from the scientific literature follow below:

a) Cardinal points on the edge of the model (Haeberling, 2002; Fosse, 2008);

b) Wind Rose (Haeberling, 2002; Fosse, 2008);

c) 2D and 3D Arrows (Burigat and Chittaro, 2007);

d) Radar (Burigat and Chittaro, 2007);

e) Use of maps associated with the itinerant mark (Fosse, 2008);

f) Grid reference (Harrower and Sheesley, 2005);

g) Compass on the horizon;

h) Jetstrip (Harrower and Sheesley, 2005).

To understand the influence of these tools in navigability and knowledge acquisition by users, this research developed a test methodology. This methodology combines different types of qualitative and quantitative tests applied to a digital map with an itinerant mark and a printed map, compared to a 3D topographic map. These tools were selected due to their characteristics that, in a critical analysis, make them clearly more intelligible to some users than others.

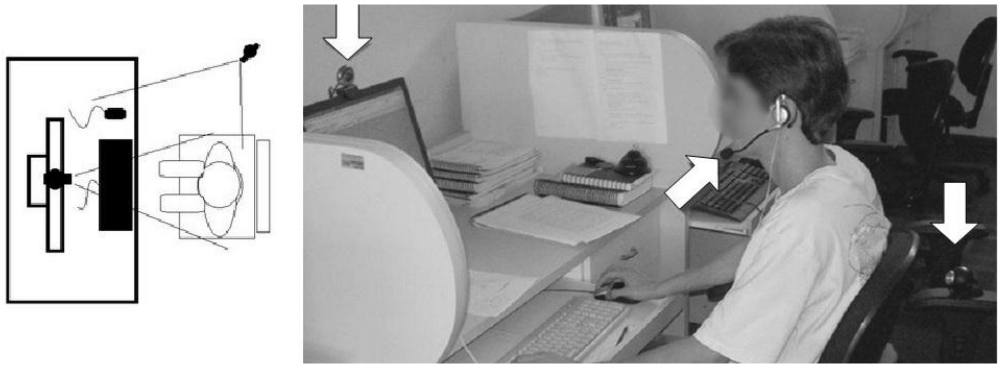
3. METHODOLOGY

3.1. Materials

3.1.1. Testing station

The tests were conducted using a testing station composed by an AMD Athlon 4000 + 2.1 GHz computer, with 1GB of RAM and Windows XP operational system, two webcams and a microphone to record users' behaviour and speech. Programs chosen for recording were STOIK Capture, used to record webcam videos; the AutoScreen 3.1 Free, used for datalogging and Kat MP3 Recorder, for recording the microphone. These programs are freeware and available online. The cameras are arranged on the computer screen, pointed to the participant's face and to their right side. This setup allows recording user actions on the computer screen as well as their facial expressions, behaviour and verbalization of actions (figure 1).

Figure 1 - Setting up the testing station.



The synchronization of the recordings was done by recording the start of each test session, placed into a single framework in order to enable the association of facial expressions and verbalization of users with their actions in the same instant. Due to the simplicity of datalogging used, the synchronization was performed with a beep activated at the beginning of the test, recorded during the filming process and on microphone. Synchrony of recordings was done with Windows Movie Maker, available on Windows XP.

3.1.3. - Characterization of the study area (test models)

For this research we used the hybrid VRML model created by Fosse (2008), from photogrammetric restitution of Macaé, RJ - Southeastern of Brazil, at 1:2000 scale. The author selected relevant information listed as elevation points and contour lines with an equidistance of 5 meters, hydrographic information, road system, vegetation and buildings in the area. For testing, the VRML models were adapted to the purposes of this study, by inserting a ball, trees and buildings in the representation. This change was carried out mainly with 3D Studio Max program, used to manipulate 3D objects and export them to VRML. In order to link the reference map and the VRML cameras to a HTML page, a javascript was created. This one links the previous two. In this way, when the user changes the VRML camera's position, the itinerant mark on reference map also changes.

3.2. Methodology

The tests were based on the accomplishment of a single task: finding a specific feature in the 3D map. This feature was a lighthouse in the preliminary tests and a red ball in the main tests. In the following sub-section the tests and criteria are described:

3.2.1. Methods of data collection

Qualitative methods can be used in the most recent pieces of research of map use and present issues related to how maps work in the construction of knowledge (Van Elzakker, 2004), and to allow evaluation of users' behaviour when operating a system. In this paper, the qualitative methods Think Aloud (Van Elzakker, 2004), and evaluation by questionnaires (Haeberling, 2002) are highlighted. There was also a datalogger to record the user's actions.

a) Think aloud: this test method consists of evaluating user's verbalization while they are using the system, giving the researcher a chance to identify problems of interpretation and to understand each process step by users (Mendonça, 2009). This test usually combines image recording and sounds of the participant's behaviour while he or she performs the test. In this method, participants have to speak out loud what they are thinking during the test. According to Van Elzakker (2004), the advantage of this method is that there is no problem of memorization or interpretation of thoughts, because they are immediately expressed. However, this method takes much time for analysis and correlation with other data about actions taken during the tests;

b) Use of questionnaires: according to Mendonça (2009), questionnaires are considered familiar accessories, cheap and generally acceptable additions to usability tests and evaluations performed by experts. A large number of filled questionnaires enhance the quality of tests, especially if compared to potentially tendentious results and variable data given by the small number of participants of usability tests or expert evaluators (Schneiderman, 1998). In this research, questionnaires are mainly used for identifying the degree of knowledge acquisition by users through the description of the way by sketch-map. In these representations, it is possible to identify characteristics of chosen points as reference points. These are the points stored in short-term user's memory and they are not necessarily the same identified during the exploring process of the map, collected by the Think Aloud method.

c) Datalogger: Data recording is presented here as a test tool, allowing analysis of users' activities through recordings of their interaction actions performed via mouse or keyboard. The use of this tool will allow evaluation of actions frequency, actions paralleling to the main task and synchronization of data obtained from other methods mentioned in the determination of critical points of navigation.

3.2.2. – Preliminary and main test sessions

The first part of tests was to determine how long the test sessions would take. The time was estimated in 20 minutes from preliminary tests with three undergraduate students of Cartographic Engineering and Post-Graduate Program in Geodetic Sciences of Federal University of Paraná. The participants used 3D maps in a similar situation of the main test, but the feature to be found was different, in this case, a lighthouse. After testing phase with the experimental group, the main tests were applied to the eight remaining participants.

Users were divided into three groups, each group being responsible for a navigation metaphor. The first group used the 3D map tool without any navigation resources; the second group used a conventional topographic paper map for 15 minutes before starting navigating; and the third group used the digital map displayed on the screen simultaneously to the model user. The conclusion of the test sessions was determined by three situations: the accomplishment of the task, withdrawal from users or time limitation set on the basis of preliminary tests in 20 minutes.

For each participant, firstly, the navigation task was verbally explained with the following statement: "Head north. At certain point, between the houses and near a church, there is a red ball. Find it and return to your starting point". The task may seem simple, but it displays three important aspects when considering the contexto of a search:

1. Initially users must locate themselves in the representation. This is accomplished through the establishment of, at least, one reference point in representation, or in the 2D map used as a reference tool;

2. The participant must establish a set of reference points during his or her navigation and concatenate them into a route in his or her cognitive map. Reports of reference points can be collected as the participant interacts with the 3D map. However, the excessive use of metaphors of navigation can decrease the number of reference points;

3. The third analysis was the consistency of routes through metaphors. A navigation tool, built from a metaphor, is considered efficient by the quantity of route parts that users can accomplish on the way back to the starting point. In the questionnaire, users who took a different path in their way back were requested to justify this decision. This analysis considers that virtual tools used may replace some landmarks and routes. This leads us to believe that the cognitive task of creating routes in a mental map has a general character, as a mental process that several users share in a similar way to achieve the same goal. In other words, in a consistent user group, there is high likelihood that there are some similarities in the way the routes are created. This affirmation requires more investigation.

At the end of test sessions, the participants answered a questionnaire with queries about user's characterization and which features were considered during navigation in 3D maps.

3.2.3. Analysis Criteria

All information collected during the tests was analyzed according to the following criteria:

Criterion 1: Selection of participants able to take the test. Difficulties with the navigation controls may restrain the interaction with the model and affect the achievement of the test. This criterion was used to exclude participants who notably failed to interact with model acceptable way to fulfill the task.

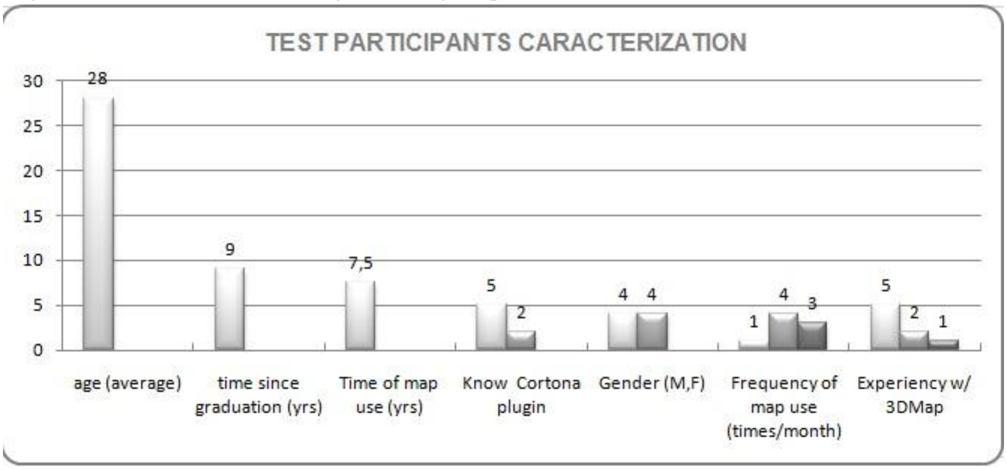
Criterion 2: Characteristic of objects used as reference. The video recordings, audio and datalogger were related on the same timeframe, which made it possible to mark introspection moments of users with the screen images and their reactions. This criterion allows gathering of evidence, whose features are used as reference points and the number of uses of metaphors guidance on the recordings.

Criterion 3: Overview of paths in the short term memory. The descriptions made by participants, conducted shortly after the end of the test, were used to evaluate which features stayed in their short term memory. The descriptions indicate which features of the model were used as reference and how the use of metaphors influenced the withholding of represented information.

4. RESULTS

The test sessions consisted of three participants in preliminary tests and 8 for the main tests, randomly chosen from the Cartographic Engineering course and the Graduate Program in Geodetic Sciences, Federal University of Parana (PPCG / UFPR), Brazil, December 2009 to January 2010. However, two main test participants were excluded by the criterion of usability of the Cortona VRML 6 plugin. This led us to have participants in more than one group in a way that a member of group 1 was also a member of group 2 or group 3. The number of participants can be explained by the fact that there were no references about the needed sample size for this kind of study and the Nielsen criterion (Nielsen, 1988) about usability for computational interfaces states that small number of participants is more than sufficient to point the most critical aspects of the interfaces. Moreover, the research objective is to evaluate the testing methodology and not the cognitive capacity of users. However, we agree and suggest that further studies should be carried out. The figure 2 presents characteristics of the participants.

Figure 2 - Characterization of the test groups.



4.1. Results of main test groups

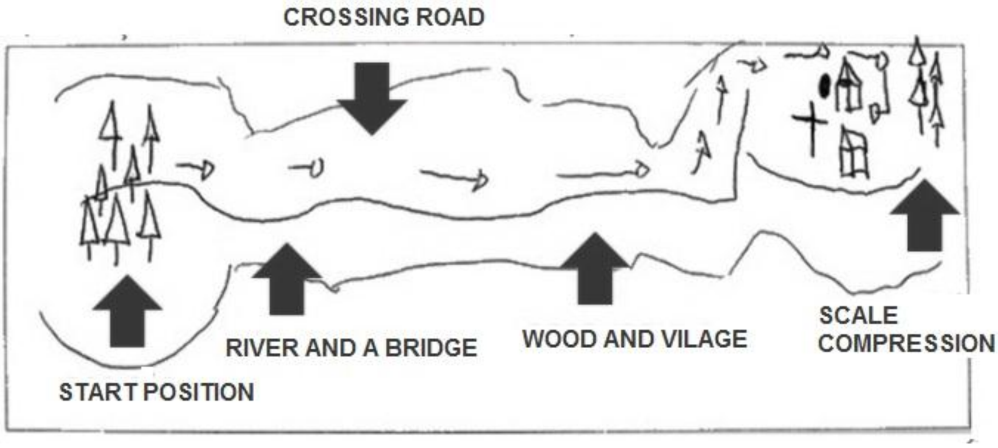
Most participants in group 1 (5 people using the 3D map only) ignored the reference points (trees and buildings) present around their initial position when they noticed a grove on a hill. Apparently, this feature served as global landmark due to its visibility from several points of the model. The symbol for churches, with towers higher than surrounding buildings and their roofs in yellow hue – something unusual for a topographic representation - made them selected as a reference point. This group took about 30% more time than the other two groups (about 17 minutes) to accomplish the navigation task and there was a higher number of recorded occurrences of participants who claimed to have felt lost. However, the sketch-map of this group presented more details comparatively to other groups.

The second group (5 people) were stimulated to use a printed map of the area for 15 minutes before interacting with the 3D map. However, all participants said they were satisfied with the map reading in less time, what later proved to be insufficient. In this group, participants expressed the use of a polygon of vegetation as a reference point, which could be seen only in one direction (from South to North, because of the hill where it was laid on). On their way back, all participants underwent a right turn instead of having followed a left turn. There were several expressions of surprise by participants who could not find the vegetation polygon. This group registered a high number of uses of linear representations and references, especially roads. This may be associated to the similarity on symbology between the printed map and the 3D map used in testing.

The third group (6 people) used the digital map with the itinerant mark. This group registered fewer cases of doubt about directions to follow and their location. However, as seen on questionnaires, the participants of this group could not recall in details the routes taken after finishing the task. This result is opposite to the first group results, which did not use any metaphor of navigation. Also, the participants tended to be more introspective. This suggests that the use and interpretation of a map puts a higher cognitive demand on users, even if there is no difficulty to mentally change their point of view between one representation and another.

An example of path sketch-map done by participants, held in the questionnaires, is presented in Figure 3. In this specific case, the participant kept only a few features as reference points, but seems to remember the path clearly. The two woods in the drawing are in the two extremes of the model, far away from the red ball, which is the solution for the navigation task. The space between the villa and the wood at the right side of sketch-map is more compressed. This could be caused because the user has not passed near it. This space compression is an example of distortion of the mental map. This figure shows that the participant didn't remember the points of route change as reference points. Another distortion noted in the figure is the position of the wood on the left in relation to his or her route – the participant placed his or her path among the trees, where, in fact, there was a river, while his or her route passed below this position in the sketch-map, out of the wood.

Figure 3: Representation of the journey made by a participant in the experiment.



5. DISCUSSIONS AND CONCLUSION

This research has addressed some aspects of navigating in 3D maps to determine the influence of guiding tools in VR environments. The analyses of the interactions and navigation problems in a test environment contributed to the establishment of a methodology in the research context for qualitative analysis of 3D topographic maps.

Tests showed that in 3D maps without any navigation resource, the construction of symbology becomes the key point for successful navigation. These results point out that global reference points tend to be more important for the navigation than local reference points, except when occlusion is present. In this case, the situation is reversed, i.e., the local reference points are requested for navigation and users don't feel comfortable in heading a specific direction if they do not have landmarks in viewing.

Evidence collected during tests suggest that lack of navigation tools at the interface of 3D maps demand a greater effort from users when they have to define their relative orientation, and this effort can develop route in mental maps quicker when compared to other evaluated methods. In tests that involve printed maps and tests with the digital map with itinerant mark (groups 2 and 3, respectively), the maps support the navigation while performing the task. However, after completing the task, users were unable to remember their path with the same details as the first group.

However, this does not exclude the possibility of errors in these mental maps. These errors will be minimized as the map reading time increases. This points out that in the 3D map the symbology should consider that some features will take as landmark independent of other reference objects, as coordinates grids or north indication. This could be an indication that to reach a consistent level of knowledge, users would have to spend as much time analyzing 3D maps as they would spend with the paper map.

With this research and its initial character, it was not possible to conclude that the use of navigating metaphors/tools contributes or not to raise participants' knowledge of one level to another. Further tests are necessary to answer this query.

The methodology has proven itself valid in the context of this research, because it allows the researcher to analyze and identify the influence of use navigation tools for identification of reference points and part of the process of the construction of mental maps by participants. The methodology has some points to be regarded, such as the amount of data generated and the huge time of analysis required, and points to be improved as the data synchronization problem and tests conditions. About this last statement, some participants may have changed their pattern of response or may have felt insecure for being in a different situation from the usual ones in which they carry out their spatial analysis. We address these statements as final questions to future works.

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REFERENCES

BURIGAT,S. e CHITTARO, L. 2007. Navigation in 3D virtual environments: Effects of user experience and location-pointing navigation aids. Int. J. Human-Computer Studies 65 (2007) 945–958. doi:10.1016/j.ijhcs.2007.07.003.

DARKEN, R.P., & PETERSON, B. (2001). Spatial Orientation, Wayfinding, and Representation. Handbook of Virtual Environment Technology. Stanney, K. Ed.

FOSSE,J. M. 2008. Proposta de orientação geográfica para as representações cartográficas tridimensionais. Curitiba. 104 p. Tese de doutorado no Programa de Pós-Graduação em Ciências Geodésicas – Universidade Federal do Paraná.

HAEBERLING, C. 2002. 3D-map presentation: A systematic evaluation of important graphic aspects. Anais: ICA Mountain Cartography Workshop "Mount Hood". International Cartographic Association. Avaiable at: http://www.mountaincartography.org/mt_hood/pdfs/haeberling2.pdf Accessed in: 21/07/09.

HAEBERLING, C., BÄR,H., HURNI,L. 2008. Proposed cartographic design principles for 3D maps: a contribution to an extended cartographic theory. Cartographica v. 43. i.3. pp.175-188. Doi:10.3138/carto.43.3.175. Accessed in:12-08-09. Avaiable at: http://web.ebscohost.com/ehost/ pdf?vid=1ehid=102esid=fdbb84ec-86ad-4835-945b-b4f1e54bd9a7%40session mgr111

HARROWER,M. e SHESSLEY,B. 2005. Moving beyond novelty: creating effective 3D fly-over maps. Anais: 22th International Cartographic Conference Mapping Approaches into a Changing World. La Coruña, Spain, July 9-16, 2005. Avaiable at: http://www.geography.wisc.edu/~harrower/pdf/ICA2005 _paper.pdf. Accessed in:24-07-09.

MENDONÇA, A. L. A. de. 2009. Avaliação de interfaces para mapas funcionais na web. Dissertação. Departamento de Geomática, Setor de Ciências da Terra, Universidade Federal do Paraná. PP 189.

SCHNEIDERMAN, B, 1998 Designing the user interface. Strategies for effective human-computer interaction. 3 ed. Addison Wesley Longman, Inc. 639p

TORY,M., MÖLLER, T., ATKINS, M.S., KIRKPATRICK, A.E. 2004. Combining 2D and 3D Views for orientation and relative position tasks. Anais: CHI 2004, V.6 N.1, Austria doi ACM:1-58113-702-8/04/0004.

VAN ELZAKKER,C. P. J.M. 2004. The use of maps in the exploration of geographic data. (Tese) Koninklijk Nederlands Aardrijkskundig Genootschap/ Faculteit Geowetenschappen, Universiteit Utrecht / International Institute for Geo-Information Science and Earth Observation. ISBN 90-6809-357-6. Labor Grafimedia b.v. – Utrecht, Netherland. Avaiable at: http://www.itc.nl/personal/elzakker Accessed in:12-12-08.

VINSON, N.G. 1999. Design guidelines for landmarks to support navigation in virtual environments. Anais: CHI '99. Pittsburgh, USA. pp. 278-285. Avaiable at: http://nparc.cisti-icist.nrc-cnrc.gc.ca/npsi/ctrl?action=rtdocean=9147118 earticle=12 Accessed in:01-08-09

WERNER, S.; KRIEG-BRÜCKNER,; B. MALLOT, H. A.; SCHWEIZER, K.; FREKSA, C. 1997. Spatial Cognition: The Role of Landmark, Route, and Survey Knowledge in Human and Robot Navigation. Anais: Informatik '97, M Jarke, K Pasedach, K. Pohl (Hrsg.), Informatik aktuell, 41-50, Berlin: Springer-Verlag. Avaiable at: http://citeseerx.ist.psu.edu/viewdoc/ summary?doi=10.1.1.2.357 Accessed in: 02-08-09