APPROACHES FOR 3D-VISUALIZATIONS AND KNOWLEDGE WORLDS FOR EXPLORATORY LEARNING

Dirk Burkhardt, Christian Stab, Kawa Nazemi, Matthias Breyer, Dieter W. Fellner

Fraunhofer Institute for Computer Graphics Research (Germany)
{dirk.burkhardt, christian.stab, kawa.nazemi, matthias.breyer, d.fellner}@igd.fraunhofer.de

Abstract

Graphical knowledge representations open promising perspectives to support the explorative learning on web. 2D-visualization are recently evaluated as gainful knowledge exploration systems, whereas 3D-visualization systems did not find their way into web-based explorative learning. 3D-visualizations and "3D Knowledge Worlds", as virtual environment in context of e-learning, comprise a high degree of authenticity, because the used metaphors are known by the users from the real world. But different challenges like the usage of 3D-Knowledge World without losing the learning context and the focused learning goals are rarely investigated and considered. New technologies provide the opportunity to introduce 3D-visualizations and environments on web to support a web-based explorative learning. Therefore it is necessary to investigate the prospects of 3D-visualization for transferring and adopting knowledge on web.

The following paper describes different approaches to use 3D-visualization and Knowledge Worlds for conveying knowledge on web-based systems using web-based contents. The approaches for 3D visualizations are classified into different layout algorithm and the knowledge worlds are classified interaction character.

Keywords: explorative learning, web-based learning, web-based visualization, 3D learning environments, semantic visualization.

1 INTRODUCTION

Information visualization is an important point in the area of e-learning, because one of the goals is to achieve an intuitive and useful way to present information to the users. By this point of view, 3D visualizations or "Knowledge Worlds" are adequate ways for information visualizations, because of their high degree of authenticity. But there is a high risk, if the metaphors from the real world will lean too much on the real world, because than the interaction becomes often to difficult, that users often get overstrained [1]. So the use of 3D visualization and Knowledge Worlds are only additive instruments, if their application is focused on the users' tasks.

Most of the time users are handling hierarchical ordered data, so that it is necessary to use adequate methods for the information visualization. In the past years the focus laid on 2D visualizations, which are an established and a quite useful way to present – of course massive once – data to the users. But up to a certain level of complexity und massively these 2D presentation methods attain a critical border. Up to that point a common method is the use of 3D based visualization, where the third dimensions can be used to show more information [2]. Furthermore with 3D data visualization a presentation can be created, which is closer to the real world [2].

3D knowledge worlds are orienting almost exclusively on the real world. This allows users often a free interaction and of course an easy to understand interaction environment.

2 APPROACHES FOR 3D VISUALIZATIONS

At first we want to describe different approaches for 3D visualizations. Overall 3D visualization can be categorized into 3 types [2]. The first are augmented 2D views, where the third dimension is only added for aesthetic purposes. The second category compasses adapted 2D visualization, where existing 2D visualizations are extended to 3D to encode additional information. The third categories are inherent 3D views, which include computations involving inherent 3D entities.

Most of the 3D visualizations, which we are presenting below, are augmented 2D views. Because of that fact, a taxonomical classification for 3D visualizations will oriented to these, which are used for 2D visualizations [4][5]. For our survey we are concentrated on the algorithmic for the layout and we extend the existing survey of Teyseyre et. al. [2].

2.1 Graph-based Visualizations

Graph-based visualizations are easy to implement visualizations which allowing a rudimental overview about data and linking's between different nodes. In different to 2D views, they often use only the third dimension for more space for presenting data. The advantage in front of the 2D implementation is the larger space, so it is possible to show 3 times more information in such a 3D Graph.

The problems by using this form of 3D visualization are similar to the 2D once, already by a larger set of linked nodes these visualizations are confusing and it is hard to find specific information. Because of the additional third dimension it becomes furthermore difficult, because there is a high risk, that nodes will be hidden by other nodes. Teyseyre et al. [2] wrote that most successful network visualizations are small ones with 10-50 nodes and 20-100 links.

2.2 Hierarchical Visualizations

The most common data type structures are hierarchical once [3]. The visualization is often realized in a tree-form. In different to the 2D views, the 3D visualizations also using a third dimension. A common challenge in all of the 3D tree-based visualization are the overlapping of nodes, relations and labels, which makes it hard to understand the complete graph by the first view.

In the following we will present some important 3D tree-based visualization, which have success and have a significant scientific approach.

2.2.1 Spanning Tree

A typical character of spanning trees is that the tree touches every node in a graph, however only a subset of the links [7]. In difference to graphs, nodes can only have one link to a parent node.

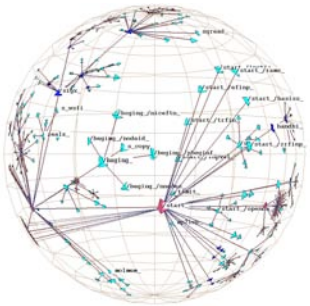

Figure 1. A sample of a Spanning Tree in 3D [7]

Spanning trees, also in 3D, allows a well overview about the visualized data. Also their relations to parent and child nodes make it easy to understand their position within the data structure. But if the dataset becomes bigger, it is difficult to find specific nodes. Furthermore it is hard to determine the hierarchic layer within a given structure. Normally every node can be classified to such a hierarchical level. Because of the spanning in 3D environment (like in Figure 1), this hierarchical level can only be identified by investing more effort.

2.2.2 Cone Tree

Cone Trees are developed directly for 3D environments, so they are not generalized by 2D implementations. Furthermore Cone Trees are one of the best known 3D graph layout techniques for information visualizations [6]. To make such cone trees usable, the interactivity and the visual aspects are essential [6].

Cone Trees are useful also for bigger datasets, as long as the navigation and information exploration follows the hierarchies from abstract to detail nodes. Only by this way of information exploration users can select and filter branches, which seem important to find the right information. Another advantage is the overview about the structure of the visualized data, so that it is suitable for semantics data, too. An example for visualizing semantics data in form of RDF, we tried in a cone tree implementation

(Figure 3). If an information exploration does not follow the hierarchy with a top-down strategy, it is hard to find information.

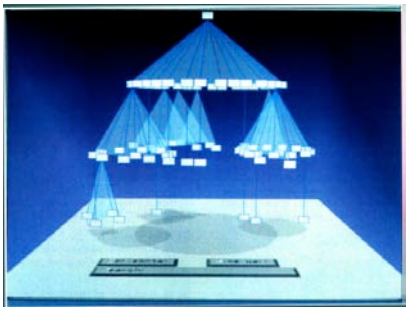

Figure 2. First implemantion of a ConeTree on Xerox [10]

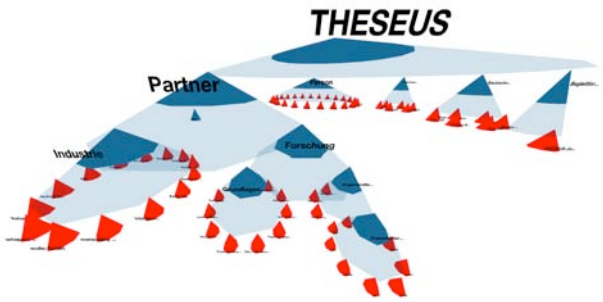

Figure 3. An implementation of the ConeTree for a semantics data source.

2.2.3 Hyperbolic Tree

Hyperbolic trees are useful for visualizing information hierarchies, specifically directed graphs with cycles [6][7]. The hyperbolic effect will be achieved by a distortion-effect on a tree data-presentation. The extending by a third dimension allows a higher information density within the space [9].

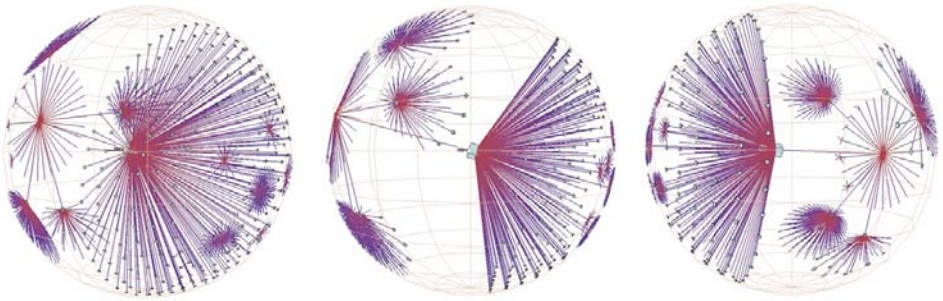

Figure 4. Example of an interaction in a 3D Hyperbolic Tree [7]

Hyperbolic Trees are often highly interactive and so they are predestined in information exploration systems, especially in the area of e-learning. This form of information visualization allows the presentation of a large number of information. But similar to Spanning Trees, these forms of information visualization have similar problems. So it is hard to find information and it is also difficult to identify the hierarchic level of a node.

2.2.4 Treemap-based Visualizations in 3D

One the most used visualizing metaphors in the academic society for presenting structured information are visualizations basing on the Treemap-metaphor, which was conceptualized by Shneiderman [26]. Since a view years this metaphor is also used for 3D views of the Treemap. The size of the rectangles or in 3D implementations, the size of the blocks, can identify some parameters like the number of containing elements, relevance for the user and so on.

Figure 5. Example of an 3D Treemap basing on semantics data

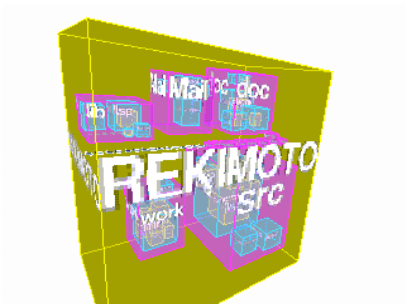

Figure 6. Information Cube as example for a Treemap-based visualization[12]

Within a Treemap, a user can quickly interact, so that it is a useful visualization for structured information e.g. semantics data to find specific information. Because of the size, users can identify relevant information also very fast. Because of that fact, we developed a concept for a 3D Treemap to visualize semantics data from an ontology (see Figure 5). Next to advantages of a 2D Treemap, the user can see a higher number of relevant information for his contextual search in a 3D implementation.

2.2.5 Misc Trees

In this category are all visualizations summarized, which basing on a tree metaphor, but could not be classified to one of the previously described approaches. Some examples of such not directly classifiable visualizations are presented in Figure 7 and Figure 8.

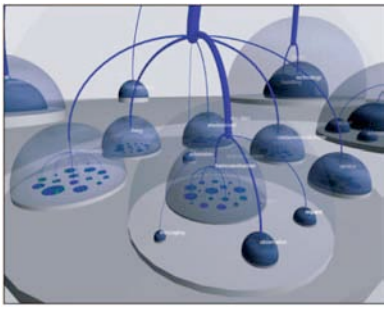

Figure 7. Hierachical Net 3D [27]

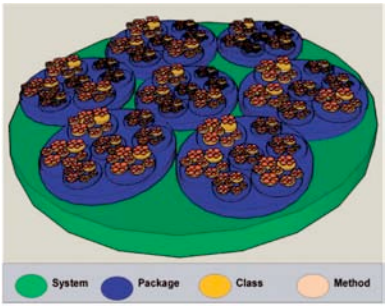

Figure 8. Circle Data Packing [28]

Often these special visualizations are developed for a specific dataset, so that they provide a good interactivity. Some of these approaches are only well for showing special characteristics. In general it is not possible to describe advantages or disadvantages to these individual approaches.

2.3 Geometrical Shape Visualizations

The use of 3D geometrical shapes is a new representation beyond graphs, which is a result of scalability and layout problems by using traditional node-link diagrams [2]. In such visualization, geometrical shapes like cuboids in different sizes and colours are used, to present different kinds of information.

2.3.1 Grid and Stack Visualization

The most common type for representing information is in form of grids or stacks. A reason for this fact is that clustering on a 3D area is easier with such cuboids shapes. Another reason is, that cuboids are most common used objects in the real world, so an abstraction for a virtual presentation is better to understand, if cuboids are used. An example for such stack visualizations is the *Triva*-system for presenting parallel running process on a computer (see Figure 9).

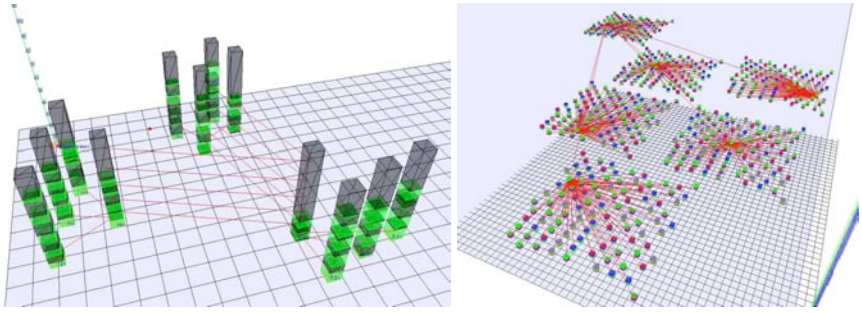

Figure 9. Two sample screenshots of a stack visualization in 3D [11]

Grid and Stack visualization are suitable for comparing different objects by visual abstract shapes with each other. Often such forms of visualizations are used for visual analytics applications.

2.3.2 Mixed Shape Visualization

Another type for shape visualizations are mixed shape visualizations, which are using different shapes. Similar to sketches for planning a room apportionment, such shapes are metaphors for real

objects. This type of information visualization is a pre-stage for 3D knowledge worlds. The difference between mixed shape visualizations and knowledge worlds is the abstraction level, which is much higher in a mixed shape world than in a virtual world.

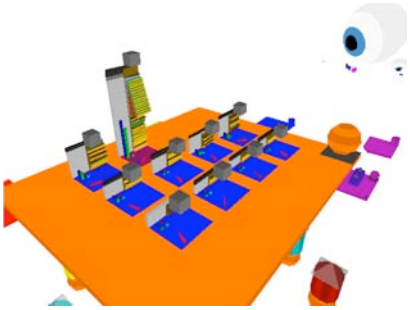

Figure 10. File Viewer with different shapes for different property indications [15]

Also this form of information visualization is suitable for comparing different objects by visual abstract shapes with each other and also this form of visualization is often used for visual analytics applications.

2.4 Landscape visualizations

The most characteristic for landscape visualizations is, that information are presented on an area, which represents a virtual landscape.

2.4.1 Geographical visualizations

A trivial use for such landscape visualizations are the use of a 3D real world applications, which basing on real geographical information, which are called Geographical Information Systems (Abbr.: GIS). One of the best known applications for that is Google Earth.

2.4.2 Data-spectrum visualizations

But landscape visualization can also be used in an abstract form for visualizing information. Early application which are using this metaphor were music programs, that visualizing the tone frequency for the complete tone spectrum and for the complete song in such a landscape visualization. In Figure 11 the landscape visualization is used to represent the relative distance of different classes by their dependencies [13].

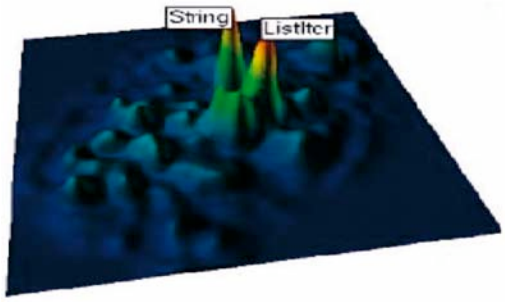

Figure 11. Example for data-spectrum visualization [13]

This abstract form of landscape visualization is often used in application for visual analytics, because obviously characteristics can easily be identified.

2.5 Misc Visualizations

Next to the previously described visualizations types, a large number of other forms exist. But they are often designed for unique scenarios and they are currently not commonly used for visualizing information. An approach that becomes more often used is the solar metaphor. This approach, we are trying for visualizing of semantics data (see Figure 13), has a lot of potential. Currently the challenge lies on the interaction, which is hard because of the freedom in such a 3D environment, so it needs too much effort to navigate to interesting information nodes.

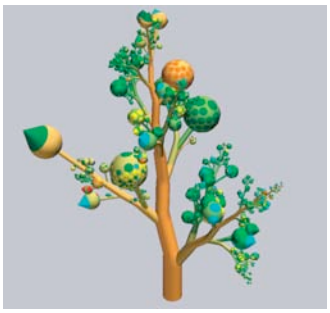

Figure 12. Example View for a Botanic Visualization [14]

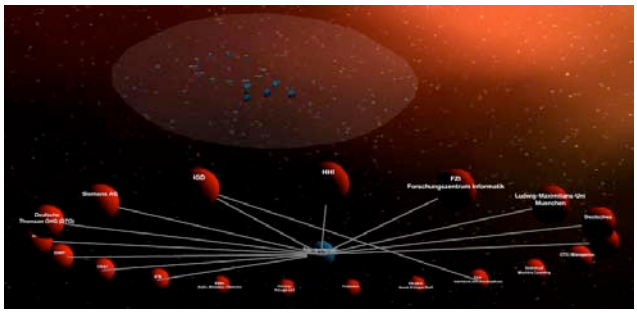

Figure 13. 3D Information Visualization of semantics data by using the solar metapher

3 APPROACHES FOR 3D KNOWLEDGE WORLDS

3D Knowledge Worlds or 3D virtual environments have a high degree of authenticity, because they are orientating very strong on the reality and reproduce it to an authentic virtual world. The goal for such 3D Knowledge Worlds by using them in e-learning context is the commitment of information to the user so that 3D Knowledge Worlds can be categorized as a special subclass of 3D Visualizations.

In this chapter we want to present some often used approaches and classifying them into a taxonomy for 3D Knowledge Worlds. The taxonomy criterions are basing on their kind of information presentation and their interaction possibilities.

3.1 Real World Metaphor

Under the classification of real world metaphor, we summarize all approaches which are leaning exact on the real world and reproduce an equivalent virtual world. A common used method is the reflexion of characteristics environment basing on the real world e.g. teaching a virtual classroom. These metaphors are easy to understand for users, because they even know these environments from their real-life experiences.

3.1.1 Virtual Classrooms

An often used environment for e-learning application is the virtual classroom. Normally the learning follows a typical teaching lesson, which can be a life-stream from a real holding lesson of a teacher, furthermore it can be a recorded session of a lesson and it can also be an interactive session, where the user chooses what he gets for a lecture presentation.

Figure 14. Teaching in Second Life [16]

Figure 15. Facilitator led v-learning event [17]

This classroom metaphor is useful, if the user should get an introduction or lecture to a specific subject. It also an easy to implement way, because often only a normal video stream and a virtual environment like *Second Life* is required, which does not need a high development and content update effort.

3.1.2 Virtual Document Archive

Another way is to use a real environment as metaphor for stored information, like *3D DocuSpace* [18]. The information will be presented in a virtual archive where a user can interactively goes through and looks for the wished documents, pictures etc.

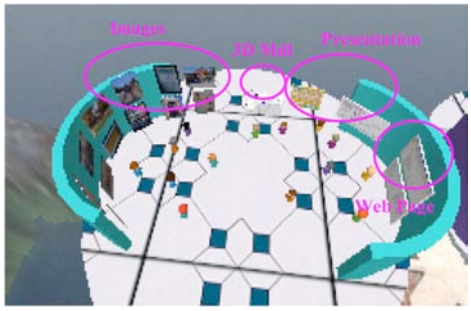

Figure 16. A 3D document management system [18]

This way of information presentation and search possibility is really interactive and for novice pc users an easy to understand way. But often the interaction is more difficult than a normal search over a search function on a form. Another problem is the low efficiency, so it often needs much more time for finding information than time is needed by traditional methods.

3.2 Entertainment-based Worlds

Entertainment-based worlds are following the idea for explorative learning. So the user can choose what kind of information is interesting for him. Because of the fact that these worlds are highly interactive, they are attractive especially for children.

3.2.1 Virtual Museum

A common way to implement an entertainment world is in form of a virtual museum. A user can walk – like in the real world – through different rooms and can inform himself about topics, which are looking interesting for him. He also is able to let topics beside, which are not relating his interests.

Figure 17. Virtual Museum [19]

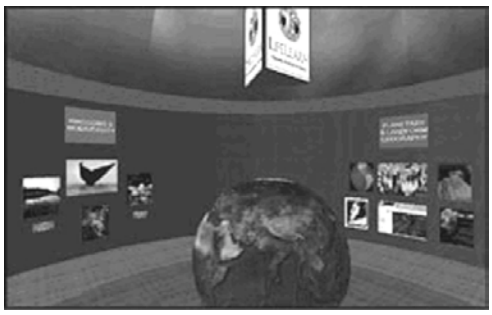

Figure 18. BioLearn – Global Simulation Center [20]

The user can freely interact through the world and inform himself to topics where he is interested in. This fact is also a disadvantage, because it can happen, that a user ignores topics, which are important for him, but they are not in his interests' sphere.

3.2.2 Role-based Exploration Worlds

A similar way like a virtual museum, are role-based exploration worlds. The world is designed like some adventure games. So the user can go through the world, wherever he wants and he has only a main goal, how he solves it, is not prescribed. In such worlds the information level can be different. In the world, which is presented in Figure 19, the level can be low, if the chat partners are not qualified or in case of predefined dialog sentences, the user has only a limited space for dialogs. In comparison to that, the information in the world, which is presented on Figure 20, is high. An advantage in that world is, that the level can be increased or reduced with harder or easier question, so that the user will not be over or undercharged.

The role-based approach allows free interaction and to the user and is highly interactive. So users can have fun during they are learning new information. An advantage is that no bigger topics can be committed to the user similar to a lesson or lecture. It is restricted to small information parts, but because of questions or repetitions they can be hold in mind for a long period of time.

Figure 19. Role Play in 3D Virtual Environments [21]

Figure 20. Interactive Gaming in Role-based Gaming [22]

3.3 Simulation and Simulators

Since many years simulators are used for teaching people for different tasks and situation. These simulations are orienting on real situation and they have to be “played” if they are being true. Simulators are also known by many normal pc users, games e.g. virtual flight simulator or train simulator had high success and allowing a realistic feeling for airplanes or trains to users. Especially for teaching pilots and other workers in high-technical environments simulators allow users to train different emergency situation without risking lives.

3.3.1 Activity Simulators

Most known applications are simulators for training staff in risk jobs or in highly technical environments. In such simulators the users get trained to solve risk situation and to deal emergency situation. This supports the staff members that they know what is to do in case of a real emergency situation and they should allow them a – as far as possible – restful handling.

Figure 21. Screenshot from the takeoff scenario in a flight simulator [23]

Figure 22. Photo from a Flight Control Tower Simulator [24]

Simulators are an established method to tech the staff for critical situations, so that they can deal it as well as possible without risking lives or high coast because of damages. Current simulators are looking really realistic because of real looking graphic engines and workstations orientating by used instruments in the real world. So often the users forget that they are only in a virtual environment, which allows training close to the real world.

3.3.2 Detailed Aspect Simulation

Another approach for simulations is simulations in form of calculations. So a user can study objectives as long and in detail he wants. It is also possible to calculate the future of such objectives, like the global warming on the earth etc. Such applications are used for specific scenarios and often they provide an easier few on the objectives like it is possible in real e.g. highlighting of brain segments with different colours.

Aspect simulators are often designed for special user groups like medicine experts. They provide information to the user, which allow him an easy understanding of special aspects. Also for calculations such simulators will help to understand special developments better than spreadsheets fully filled with numbers.

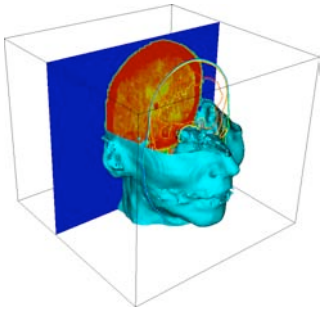

Figure 23. Medical Image for simulation on a human head [25]

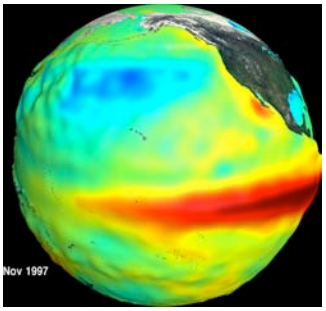

Figure 24. Simulation of sea surface temperature anomalies by color [25]

4 DISCUSSION

For creating an intuitive to use 3D visualization the most success had visualization, which is designed directly for a 3D environment. So they will use the dimension in an optimal way. Also 3D Visualizations have a great success, where the information is bind to the dimension. Augmented 2D visualizations are often difficult to use for users, because they often use the third dimension only for more space, so that a user will get presented a too large number of information, so that he is overcharged in consequence.

For creating useful 3D knowledge worlds, the mixture of entertainment, interactivity and form of information presentation (e.g. like virtual museum or classroom) is important. An overweight of only one of these aspects will end in an unattractive application.

5 CONCLUSION

In this paper we tried to classify different approaches in 3D visualizations and 3D knowledge worlds. We also tried to show the advantages and chances and also their disadvantages and possible existing problems. This overview of approaches and advices to these should be considered before an e-learning application will be designed.

Next to the classification we gave general information before starting to create a new 3D visualization or knowledge world. In general it is not possible to give ordinary information for design a successful visualization, but it will help to regard basic aspects.

REFERENCES

[1] Shneiderman, B.: "Why not make interfaces better than 3D reality?", Computer Graphics and Applications, IEEE , vol.23, no.6, pp. 12- 15, 2003.

[2] Teyseyre, A.R.; Campo, M.R.: "An Overview of 3D Software Visualization", IEEE Transactions on Visualization and Computer Graphics, vol.15, no.1, pp.87-105, 2009.

[3] Garrett, J.: “The Elements of User Experience”, New Riders, Berkeley, 2002.

[4] Keim, D.: “Visual Techniques for Exploring Databases”, Invited Tutorial, Int. Conference on Knowledge Discovery in Databases, Newport Beach, CA, USA, 1997

[5] Keim, D.: “Visualization Techniques for Mining Large Databases: A Comparison”, Transactions on Knowledge and Data Engineering, pp. 923-938, 1996.

[6] Herman, I.; Melancon, G.; Marshall, M.S.: "Graph visualization and navigation in information visualization: A survey", IEEE Transactions on Visualization and Computer Graphics, vol.6, no.1, pp.24-43, 2000.

[7] Munzner, T.: "Exploring large graphs in 3D hyperbolic space*", IEEE Computer Graphics and Applications*, vol.18, no.4, pp.18-23, 1998.

[8] Munzner, T.; Burchard, P.: “Visualizing the structure of the World Wide Web in 3D hyperbolic space”, Proceedings of the First Symposium on Virtual Reality Modeling Language,San Diego, California, United States, 1995.

[9] Benford, S.; Taylor, I.; Brailsford, D.; Koleva, B.; Craven, M.; Fraser, M.; Reynard, G.; Greenhalgh, C.: “Three dimensional visualization of the World Wide Web”, ACM Comput. Surv. 31, 4es, 1999.

[10] Robertson, G.; Mackinlay, J.; Card, S.: “Cone Trees: animated 3D visualizations of hierarchical information”, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems: Reaching Through Technology, Eds. CHI '91. ACM, New York, NY, pp. 189-194, 1991.

[11] Schnorr, L.; Huard, G.; Navaux, P.: "3D approach to the visualization of parallel applications and Grid monitoring information", IEEE/ACM International Conference on Grid Computing, pp. 233-241, 2008.

[12] Rekimoto, J.; Green, M.: " The Information Cube: Using Transparency in 3D Information Visualization", Proceedings of the Third Annual Workshop on Information Technologies & Systems (WITS'93), 2008.

[13] Telea, A.; Voinea, L.: "A framework for interactive visualization of component-based software", Proceedings of 30th Euromicro Conference, pp. 567- 574, 2004.

[14] van Wijk, J.: "Views on Visualization", IEEE Transactions on Visualization and Computer Graphics vol.12, no.4, pp. 421-433, 2006.

[15] Young, P.; Munro, M.: "Visualising software in virtual reality", Proceedings of 6th International Workshop on Program Comprehension (IWPC '98), pp.19-26, 1998.

[16] Callaghan, M.; McCusker, K.; Losada, J.; Harkin, J.; Wilson, S.: "Integrating virtual worlds & virtual learning environments for online education", International IEEE Consumer Electronics Society's Games Innovations Conference (ICE-GIC), pp.54-63, 2009.

[17] Cai, H.; Sun, B.; Farh, P.; Ye, M.: "Virtual Learning Services over 3D Internet: Patterns and Case Studies", IEEE International Conference on Services Computing (SCC '08), vol.2, pp.213-219, 2008.

[18] Sun, T.; Karlsson, J.; Peng, W.: "Collaborative 3D DocuSpace: A platform for next-generation document services in 3D virtual worlds", IEEE/INFORMS International Conference on Service Operations, Logistics and Informatics (SOLI '09), pp. 291-294, 2009.

[19] Danilicheva, P.; Klimenko, S.; Baturin, Y.; Serebrov, A.: "Education in Virtual Worlds: Virtual Storytelling", International Conference on CyberWorlds (CW '09), pp. 333-338, 2009.

[20] Corbit, M.; DeVarco, B.: “SciCentr and BioLearn: two 3D implementations of CVE science museums”, Proceedings of the Third international Conference on Collaborative Virtual Environments, ACM, New York, pp. 65-71, 2000.

[21] Nazemi, K.; Bhatti, N.; Godehardt, E.; Hornung, C.: „Adaptive Tutoring in Virtual Learning Worlds”, Association for the Advancement of Computing in Education (AACE): Proceedings of ED-Media 2007 World Conference on Educational Multimedia, Hypermedia & Telecommunications, Chesapeake, pp. 2951-2959, 2007.

[22] Blas, N.; Paolini, P.; Poggi, C.: "3D worlds for edutainment: educational, relational and organizational principles", Workshops. Third IEEE International Conference on Pervasive Computing and Communications Workshops (PerCom), pp. 291- 295, 2005.

[23] Natho, N.; Pfeiffer, O.: "A Knowledge Management System for Educational Scenarios in 3D Virtual Worlds", Second International Conference on Mobile, Hybrid, and On-Line Learning (ELML '10), pp. 136-140, 2010.

[24] MacDill Air Force Base Shows Off Tower And Flight Simulators, http://southtampa2.tbo.com/content/2009/feb/26/261556/macdill-shows-its-bells-and-whistles---oh-and-simu/, 2009.

[25] Brodbeck, D.; Mazza, R.; Lalanne, D.: “Interactive Visualization - A Survey”, Human Machine Interaction, Springer Verlag, Berlin, 2009.

[26] Shneiderman, B: “Tree visualization with tree-maps: 2-d space-filling approach”, ACM Trans. Graph, Vol. 11, Is. 1, pp. 92-99, 1992.

[27] Balzer, M.; Deussen, O.: “Hierarchy Based 3D Visualization of Large Software Structures”, IEEE Visualization Proceedings of the Conference on Visualization '04, IEEE Computer Society, Washington DC, p. 598.4, 2004.

[28] Wang, W.; Wang, Hu.; Dai, G.; Wang, Ho: „Visualization of large hierarchical data by circle packing”, Proceedings of the SIGCHI Conference on Human Factors in Computing Systems, CHI '06, ACM, New York, pp. 517-520, 2006.

[29] Burkhardt, D.; Nazemi, K.; Bhatti, N.; Hornung, C.: “Technology Support for Analyzing User Interactions to Create User-Centered Interactions”, HCI International 2009, San Diego, pp. 3-12, 2009.

[30] Nazemi, K.; Breyer, M.; Hornung, C.: “SeMap: A Concept for the Visualization of Semantics as Maps”, HCI International 2009, San Diego, pp. 83-91, 2009.

Citation:

Burkhardt, Dirk; Stab, Christian; Nazemi, Kawa; Breyer, Matthias; Fellner, Dieter W.:
Approaches for 3D-Visualizations and Knowledge Worlds for Exploratory Learning.
In: Gómez Chova, Luis (Ed.) u.a.; International Association of Technology, Education and Development (IATED):
International Conference on Education and New Learning Technologies. Proceedings [CD-ROM] : EDULEARN10.
Valencia : IATED, 2010, pp. 006427-006437