Guest Login – Visitor-Centred Information Design

Jan Wojdziak, Martin Zavesky, Ingmar S. Franke, Christian Lambeck, Rainer Groh
Technische Universität Dresden, Institute of Software and Multimedia Technology, Dresden, Germany
Nöthnitzer Straße 46, 01187 Dresden, Germany
Jan.wojdziak@tu-dresden.de

Projection of three-dimensional space onto a two-dimensional surface relies on the computer graphics camera based, which is designed like the camera obscura. The procedure follows the laws of perspective projection and does not explicitly consider the viewer of the rendered image. Our approach is to extend this camera model in order to involve human perception into the rendering of three-dimensional scenes. The aim is to create a user-centred spatial impression by a two-dimensional image. By integrating the user into this process, implicit interactions can be applied to provide interfaces for an efficient and coherent communication of information in virtual environments. This paper introduces user-specific and context-specific parameters that must be taken into account when designing presence-aware applications. To this end, we present a concept of an interactive exhibition based on implicit interaction and point out its applicability in information design of three-dimensional scenes.

User-centred visualization, implicit interaction, perception, presence-aware application, three-dimensional computer graphics

1. INTRODUCTION

User interaction goes beyond from mouse and keyboard and becomes increasingly natural and physical. In recent years, affordable hardware devices have been developed that allow the implementation of multimodal user interfaces. New technologies permit the development of new interaction methods with the aim of providing intuitive human-computer interaction using graphical user interfaces. This claim is valid for two-dimensional as well as three-dimensional interfaces and covers a wide range of using scenarios from entertainment to science. An appropriate visual representation can convey the comprehension of unstructured and complex data more clearly to the viewer. In order to establish comprehensible information visualizations, it is important to preprocess the underlying data for reasons of efficiency and effectiveness. As more and more different technologies are combined, the role of interaction between user and system in interface design becomes a crucial aspect (Bertoline 1998).

For the scope of this paper, implicit interaction is analyzed in the context of interfaces that assist users in perceiving spatial information as effectively and efficiently as possible (Jokela et al. 2003). Consequently, we discuss the standard camera model in computer graphics. An extended model is presented that considers human visual perception. The aim is to integrate characteristics of the user into real-time applications. Hence, assistance for the user in perceiving spatial information can be increased. With advances in real-time computer graphics, user interfaces that are effectively invisible, or become invisible with successive learned interactions, establish a natural and intuitive real-time communication process between user and system.

Our approach is to make use of implicit, presence-aware interaction techniques to create user-centred visualizations. Additionally, user-specific requirements and cognitive load in handling three-dimensional interfaces can be reduced. The approach is illustrated by a concept and implementation of an interactive application. This contribution discusses related work and describes our user-centred information design in more detail. The focal point is the identification and implicit integration of the user into the rendering of three-dimensional scenes in virtual environments.

2. RELATED WORK

In (C. Ware 2004), Ware presents key principles for the creation of information visualizations including cognitive principles and a guide to human visual perception. Based on the visualization pipeline by Card et al. (Card et al. 1999), Shneiderman

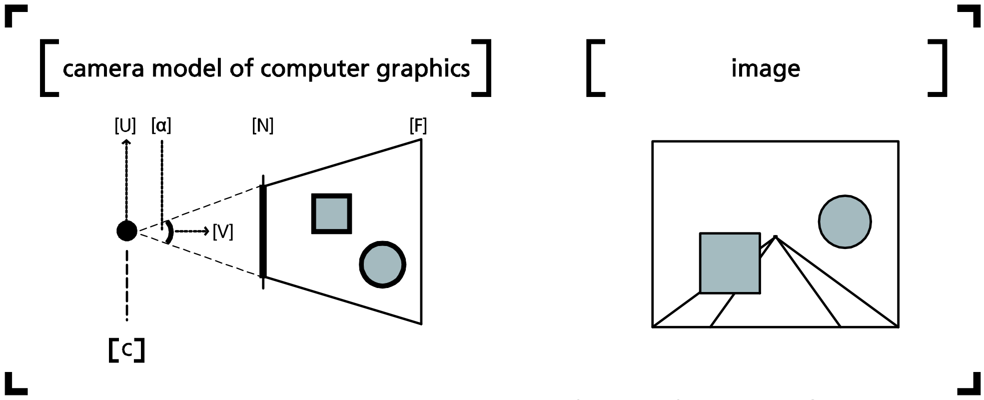

Figure 1: *The common computer graphics camera model consists of centre of projection [C], viewing direction [V], field of view [α] and up-vector [U] as well as view frustum with near clipping plane [N] and far clipping plane [F]*

describes essential guidelines for creating information visualizations with his Visual Information Seeking Mantra (Shneiderman 1996). For instance, these methods and guidelines are used in (Feldt et al. 2005) and (Roberts 2007) to explain complicated facts and relationships in two-dimensional visualizations. The authors argue that three-dimensional visualizations should use these guidelines and methods as well.

Non-photorealistic rendering (NPR) is an essential discipline in the context of three-dimensional visualizations (Strothotte & Schlechtweg 2002). This technique typically produces images of three-dimensional scenes that have been modified from the original input to convey an artistic style. In interactive environments, NPR techniques can be used to visualize information in virtual environments. This can be achieved by manipulating the standard camera model of computer graphics (Agrawala et al. 2000; Singh 2002; Yu & McMillan 2004), the image plane (Zelnik-Manor et al. 2005; Carroll et al. 2009) and the object geometry (Franke et al. 2007). Non-photorealistic rendering can also be used for user-centred visualizations (Wojdziak, Zavesky, et al. 2011). The interface can convey information by adapting to the physical presence of the viewer.

The field of interactive computer systems reaches beyond the presentation of images on the screen. User input and the system's response are fundamental in this field of research. It explores a variety of input and output technologies, ranging from multi-touch systems (Bill Buxton 2008; Han 2006) and 3D gesture interaction (Balakrishnan & Kurtenbach 1999; Owen et al. 2005; J. C. Lee 2008) to augmented reality (Azuma, others 1997; Kato & Billinghurst 1999). The aims are to increase the accessibility and reach of interactive procedures and technologies in order to achieve user satisfaction. The methods of current human-computer interaction are dominated by explicit interaction techniques. The user is actively engaged in the process, for instance by means of keyboard, mouse or touch interaction. Implicit interactions are methods and techniques that use presence-aware interactions and everyday actions of the user. Schmidt defined this kind of interaction as follows:

"*Implicit Human Computer interaction is an action, performed by the user that is not primarily aimed to interact with a computerized system but which such a system understands as input"* (Schmidt 2000) *, p.192*

A number of contributions demonstrate the shift from explicit HCI towards a more implicit way of interaction (Schmidt, range paper). Therefore, it is necessary to define interaction zones that the user has to use to handle the system. These zones involve the distance between user and screen (Streitz et al. 2003) as well as the viewing direction and body orientation (Vogel & Balakrishnan 2004) to enhance explicit interaction with implicit interaction techniques. The current field of application reaches from usability tests (Antifakos et al. 2003), self-adapting interfaces (Dietz et al. 2004) and user profile creation to advanced visualization techniques for data representation (Ju et al. 2008).

3. INTERACTIVE VISUALIZATIONS

Visualizations of three-dimensional scenes based on implicit interaction techniques have to consider the user and his surrounding, i.e. they have to be presence-aware. Implicit interactions initiate the shift from explicit HCI towards a more implicit use of technical systems. Therefore, the user is not forced to learn how to interact with a system. The system maintains information about ambient conditions including for instance position, number of users, age or gender. By integrating these data, three-dimensional scenes can be processed in a user-centred manner. This can be achieved by the extension of the camera model in computer graphics.

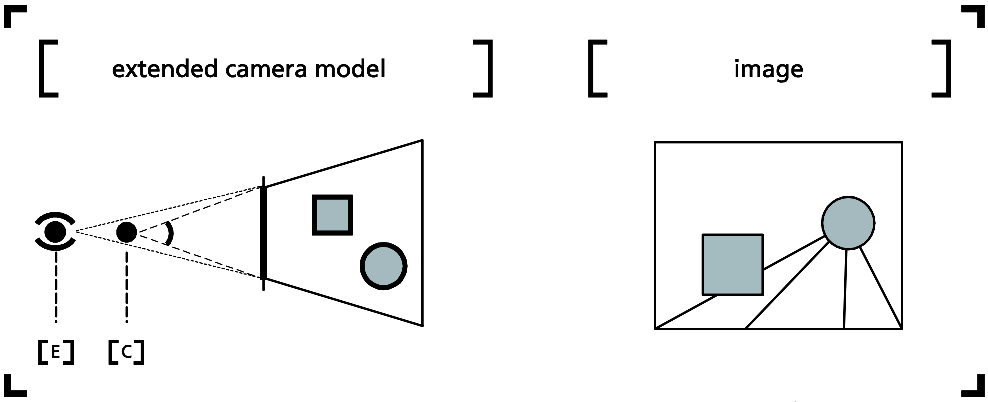

Figure 2: *The extended computer graphics camera model. The position and orientation of the viewer [E] are integrated into the camera model. The principle vanishing point of the image is adapted to the viewer.*

3.1 Camera model in computer graphics

The standard computer graphics camera model maps virtual, three-dimensional space onto a two-dimensional surface. The procedure follows the laws of perspective projection (Angel 2002; Foley 1995). The computer graphics camera model as shown in *Figure 1* contains a view frustum as well as the centre of projection [C], the viewing direction [V] and the up-vector [U]. The view frustum is defined by the aspect ratio of the projection plane and also near [N] and far [F] clipping plane. One aspect is considered insufficiently in the standard camera model: the human being and its visual perception. Coincident to (Franke et al. 2008), we argue that the viewing behaviour has to be considered in the process of user-centred interfaces design.
The view of the observer on the image plane and the rendered image is not related to the perspective of the camera into the virtual scene. To reduce this discrepancy, the user can move his head to the corresponding position to reconstruct the situation in space of the three-dimensional scene. Therefore, the viewer perceives the same perspective impression of the scene. This works comparatively well as long as the new eye position does not differ too much from its requested position. If not, the perception of the image differs significantly from the intended camera position (Glaeser 2008).
Analyzing Renaissance paintings reveals that the artists were faced with the same challenges as current computer graphics: to map a three-dimensional scene onto a two-dimensional plane (Groh 2007; Hockney 2006; W. R. Ware 1914). But there is a main difference between paintings and computer generated images: The ”device” for creating projections. A computer system calculates an image based on geometrical rules of projection. Artists integrate a “human factor” into these rules because they construct paintings according to their own (human) visual impression. To integrate the “human factor” and its applicability in computer generated images, a user-centred camera model is defined.

As shown in *Figure 2*, the centre of projection of the observer [E] is integrated into the camera model. The observer’s view on the image plane is defined by the so called **secondary perspective** [2]. The secondary perspective is the pseudo-perspective, of the viewer looking at a flat perspective image from another viewpoint. This component integrates the visual human perception as a parameter into the model. The viewer or more precisely the real eye [E] has a position and an alignment.

3.2 Implicit Interaction

The extended model can be used in interactive and presence-aware applications. The user interacts with a three-dimensional scene in a certain environment. Implicit interaction is based on the assumption that the system has a certain understanding of the context. More precisely, the context includes the users’ behaviour and the surroundings in a given situation. For the development of a presence-aware application, three main aspects have to be considered:

(i) Scenario categorization – These are the parameters of the application context

(ii) Tracking and computation – includes tracking devices and methods to determine position and alignment of a user

(iii) Adaptation – This is the adaptation of the interface layout depending on the attributes of the scenario and the tracking results

3.3 Scenario categorization

The first step in designing presence-aware applications is the definition of the context parameters. In the following, essential categories with their characteristics are introduced.

User position and alignment
X-coordinate - The x-coordinate defines the position of the user parallel to the screen.

Therefore, lateral movement of the user can be considered.
Y-coordinate - The y-coordinate defines the height of the user in relation to the screen. Vertical movements as well as the size of the user can be regarded.
Z-coordinate - The z-coordinate defines the distance between the user and the screen. Movements that are orthogonal to the display can be considered.
Alignment - The orientation of a person in relation to the screen can be detected by the alignment. It is defined by the angle relative to the screen.

Spatial Structure
The distance between the observer and the display is essential for the presentation and also one of the most important characteristics of presence-aware application. The local situation and the spatial structure take part in decision-making of the possibilities in interface design. The following itemization stipulates four different spatial situations with an increasing number of degrees of freedom:
Close-up Range - The close-up range refers to scenarios where the user interacts within the immediate vicinity of the screen (up to one meter). A shift of the distance is in the range of centimetres. The primary trackable body part is the head.
Corridor - The corridor is a spatial structure where the interaction space is limited to a narrow strip. The movement of the user is almost linear. This is accompanied by a restriction of the users' degrees of freedom.
Interior room - The interior is a room in the conventional meaning. Distances are normally not more than ten meters. Users can approach the screen from many directions.
Outside section - In outside sections, the distance between user and screen can be larger than in other spatial situations. Areas of outside sections are squares, streets and other public places. Users can arrive from almost all directions.

Screen size:
The size of the screen and thus possible visualization adaptations influence the information design decisively. The size affects the amount of presentable information and the type of visualization. In this contribution, display size is itemized into three categories:
Small - A small screen size describes a size not greater than 17''. This includes mobile devices, but also smaller desktop systems.
Medium - Medium sized screens have screen dimensions up to 50'' and thus cover the majority of television sets and larger monitors.
Large - A large screen size describes a device greater than 50''. This includes Multi-monitor set-ups, beamer installations and especially large canvas.

3.4 Tracking and Computation

The aspect of tracking devices and methods is essential in the design of applications. There is a variety of technologies and algorithms for determining the position and the identification of characteristics of the given surroundings. The following discussion highlights some concepts and methods for the use in the field of presence-aware applications. For instance, web camera based approaches as well as Nintendo Wii Remote or Microsoft Kinect can be used for tracking the position and orientation of a single user or multiple users. In some scenarios it may be necessary to detect a person but also to differentiate between users. Based on the face of a user, identification methods were developed and can be utilized (Turk & Pentland 1991; Yuille et al. 1992). Another specialization is the identification of a specific person to assign their individual user profile. Despite their potentials, these methods are computationally expensive and are still rarely used in interactive applications. However, a detailed discussion of this topic is out of scope of this contribution. It is assumed that tracking devices and algorithms meet the requirements of presence-aware applications in the given context.

3.5 Adaptation

The adaptation of the visualization in relation to the user and his alignment is the final step in the design of user-centred visualizations. Based on the scenario categorization and the tracking parameters, different interface adaptations have to be defined. In the following, an application for an interactive exhibition is presented to clarify interface adaptation for three-dimensional virtual environments.

4. INTERACTIVE EXHIBITION

In order to establish digital information visualizations especially as a part of an interactive exhibition, it is important to prepare the underlying data. The type of presentation as a task of the system is responsible for the knowledge transfer to the viewer. For presence-aware applications, no technical requirements and little cognitive load in handling should be needed to interact with the visualizations.

4.1 Concept

Our concept of an interactive installation is shown in *Figure 3*. Visitors walk past a large display and a tracking system detects their position and alignment. The two-dimensional screen shows information of a three-dimensional scene. The information is always displayed in front of the observer (see 1 in *Figure 3*). This shows the implementation of the x-coordinate of the viewer's eye position (secondary perspective). If the visitor moves closer the screen, relevant information is presented (see 2 in *Figure 3*). For that, a zoom as an implementation of the z-coordinate is integrated into the installation for example for detail in context visualizations. The y-coordinate can be used to define the vertical position of the information on the display. Another possibility is to adjust content of the presentation to tailor the information to children and adults accordingly (see 3 in *Figure 3*). The orientation of a person determines whether the visitor is looking at the display (see 4 in *Figure 3*). Consequently, detailed information is only shown if needed. This also serves to prevent unnecessary information overload.

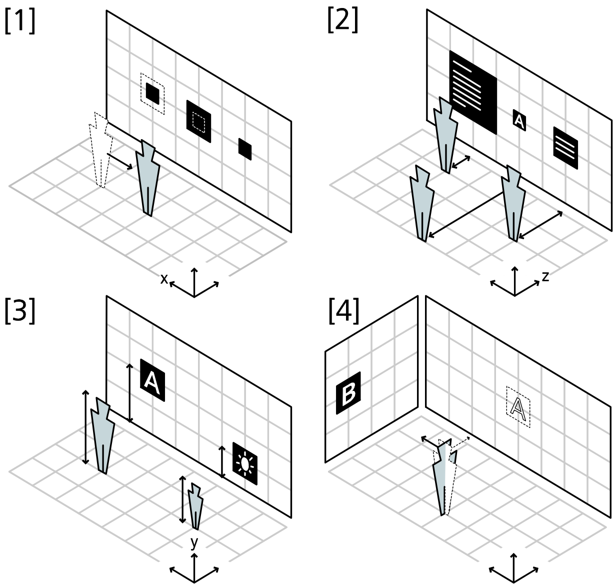

Figure 3: *Mode of operation by the extended camera model based on position and orientation of a viewer in the implementation of x-coordinate [1], z-coordinate [2], y-coordinate [3], orientation [4]*

4.2 Realization

Based on the aspects of the previous section, the scenario conditions have to be defined first. This includes user-depended parameters as well as spatial structure and display size. Subsequently, the identification and evaluation of hardware and software that meets the requirements based on the scenario categorization is necessary. The user tracking has to be taken into account. Depending on the defined and tracked parameters, the interface has to be adapted accordingly.
This kind of research in the context of novel visualization and interaction techniques requires interactive computer systems. To this end, a component-oriented software framework is used in the field of interactive applications. Bildsprache LiveLab (BiLL) allows implementation and combination of different components, responsible for various tasks. BiLL is a framework focussing on three-dimensional computer graphics and enables the combination of modules that implement different algorithms to enhance, modify and influence visualization and interaction techniques (Wojdziak, Kammer, et al. 2011).
The scenario of an interactive exhibition in the context of three-dimensional scenes has context-dependent parameters. The spatial structure in this scenario is set as interior room. Therefore distances up to ten meters between user and display are possible. The users are various visitors of the exhibition. The screen size depends on the kind of exhibition. Displays of all sizes are imaginable in this scenario. However, in this example, a canvas (large screen) is used. The initial three-dimensional scene is shown in *Figure 4*. Three cars are visualized in a perspective projection. Without a tracked user the image is rendered based on the standard camera model of computer graphics (cp. *Figure 4*). As soon as a person enters the interaction zone, he is tracked by a Microsoft Kinect. OpenNI framework (OpenNI organization 2010) transmit the detected information of the user to the Bildsprache Livelab framework. Simultaneously, the visualization is adapted according to the position of the user.

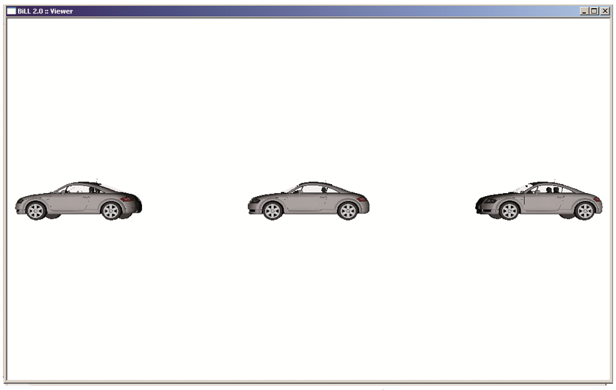

Figure 4: *The initial visualization of a three-dimensional scene without a tracked user showing three cars in a perspective projection*

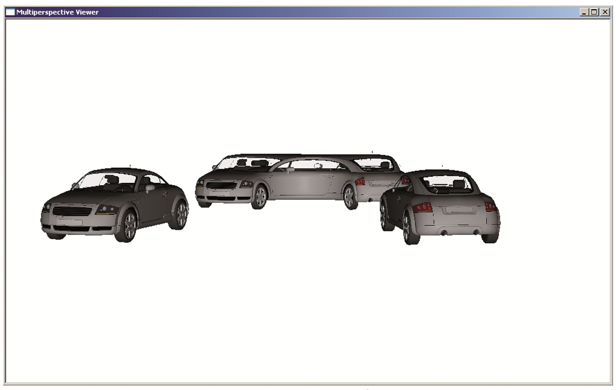

Figure 5: *Multiperspective view of the three-dimensional scene. The user is located in the centre (x- and y-coordinate) in front of the display. The interface renders a multiperspective view in the central area and a perspective view in the outer regions*

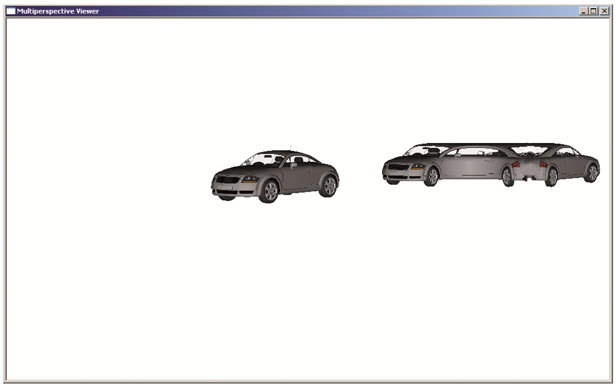

Figure 6: *Multiperspective View of the three-dimensional scene. The user is located in the vertical centre (y-coordinate) and on the right side (x-coordinate). The interface renders a multiperspective view on the right side of the screen and a perspective view in the middle and on the right side.*

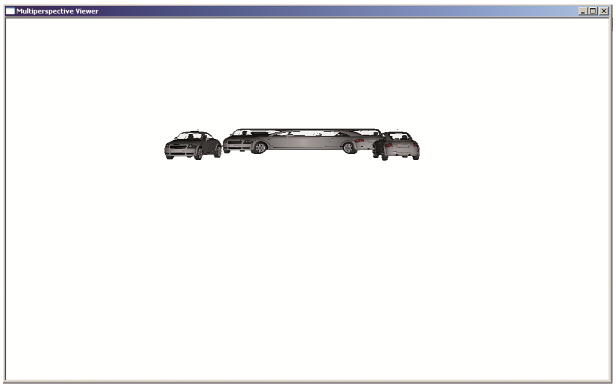

Figure 7: *Multiperspective View of the three-dimensional scene. The users' head is located above the middle of the display (y-coordinate), in the horizontal centre (x-coordinate). The distance to the display (z-coordinate) is larger than in Figure 5. The interface renders a multiperspective view on in the middle and a perspective view on the left and on the right side.*

The adaptation of the visualization for a user that is located in the middle of the screen as shown in *Figure 5*. A multiperspective view is visualized in the region that is corresponding to the user (x-coordinate). For instance, in *Figure 6* the user is located on the right side of the display. In *Figure 7*, the user is detected in the middle of the screen. In comparison to *Figure 5*, the user has changed his position in y- and z-dimension. Accordingly, the interface adapts the visualization dependent on the y- and z- coordinates. The scene is visualized on the eye level of the user (y-coordinate) and a camera zoom is integrated dependent on the distance between user and display (cp. *Figure 7*).

5. CONCLUSION

This contribution illustrates the potential of implicit interactions in presence-aware applications. The means interactions with new hardware devices as well as the visualization of information itself are essential for their success. An extended camera model of computer graphics was presented. The extension consists of the integration of characteristics of humans into the rendering of three-dimensional scenes. After analyses of the camera model in computer graphics, issues in the context user-centred visualizations were described. The integration of an extended camera model is of particular importance to achieve the benefits of visualizations that assist the user in perceiving information.

Furthermore, describing parameters for implicit interaction were identified. These were incorporated into the design of an interactive exhibition. Based on this concept, by using a real-time environment, an implementation of an interactive user-centred visualization was developed. Implicit HCI was defined as an action, performed by the user that is not primarily aimed to interact with a computerized system but as an interaction possibility to establish intuitive communication between user and system.

It was further identified, that user- and context dependent parameters and their tracking as well as their interpretation are key concepts for implicit human-computer interaction.

6. FUTURE WORK

With the BiLL framework as an interactive computer system, open research questions about the effective and efficient perception of information can be pursued with great ease. In the future, tracking technologies will enable a wider range of user input, including speech, gestures and whole body interaction. This offers possibilities to broaden the range of human-computer interaction in order to explore interaction with applications such as CAD-systems beyond mouse and keyboard.

The next steps embrace the implementation of different adaptations, for instance of semantic or geometric zoom. Therefore, an expansion of possible interface adaptations for a given content can be achieved. With the growth of possibilities in the area of the interface adaptation and in the area of tracking technology and computation, a guideline to user-centred applications is necessary. „Best Practice“ approaches exist only in sub domains. An enclosing, extensible and modular approach is required. From a developer's point of view, it is important for design, reuse and maintenance.

7. ACKNOWLEDGEMENTS

Europa fördert Sachsen.

Jan Wojdziak, Martin Zavesky and Christian Lambeck thank European Social Fund (ESF), the European Union and the Free State of Saxony.

Rainer Groh and Ingmar S. Franke thank Deutsche Forschungsgemeinschaft (DFG) (WaRP, DFG-GZ:GR 3417/1-1.).

8. REFERENCES

Agrawala, M., Zorin, D. & Munzner, T., 2000. Artistic Multiprojection Rendering. In Proceedings of the Eurographics Workshop on Rendering Techniques 2000. Eurographics Workshop on Rendering Techniques. Springer, pp. 125-136.

Angel, E., 2002. Interactive computer graphics, Addison-Wesley.

Antifakos, S., Schiele, B. & Holmquist, L.E., 2003. Grouping mechanisms for smart objects based on implicit interaction and context proximity. In Adjunct Proceedings of International Conference on Ubiquitous Computing (Ubicomp), Seattle, USA.

Azuma, R.T., others, 1997. A survey of augmented reality. Presence-Teleoperators and Virtual Environments, 6(4), p.355–385.

Balakrishnan, R. & Kurtenbach, G., 1999. Exploring bimanual camera control and object manipulation in 3D graphics interfaces. In Proceedings of the SIGCHI conference on Human factors in computing systems: the CHI is the limit. CHI \uc0\u8217{}99. New York, NY, USA: ACM, p. 56–62.

Bertoline, G.R., 1998. Visual science: an emerging discipline. Journal for Geometry and Graphics, 2(2), p.181–187.

Bill Buxton, 2008. Two-Handed Input in Human-Computer Interaction. In Haptic Input.

Card, S.K., Mackinlay, J.D. & Shneiderman, B., 1999. Readings in information visualization: using vision to think, Morgan Kaufmann.

Carroll, R., Agrawala, M. & Agarwala, A., 2009. Optimizing content-preserving projections for wide-angle images. In SIGGRAPH \uc0\u8217{}09: ACM SIGGRAPH 2009 papers. New York, NY, USA: ACM, p. 1–9.

Dietz, P. et al., 2004. Multi-projectors and implicit interaction in persuasive public displays. Proceedings of the working conference on Advanced visual interfaces, p.209–217.

Feldt, N. et al., 2005. Tailor-made exploratory visualization for statistics Sweden. In Third International Conference on Coordinated and Multiple Views in Exploratory Visualization (CMV 2005). Coordinated and Multiple Views in Exploratory Visualization, 2005. (CMV 2005). pp. 133-142.

Foley, J.D., 1995. Computer graphics: principles and practice, Addison-Wesley Professional.

Franke, I.S. et al., 2008. Towards attention-centered interfaces. ACM Transactions on Multimedia Computing, Communications, and Applications, 4(3), pp.1-13.

Franke, I.S., Zavesky, M. & Dachselt, R., 2007. Learning from Painting: Perspective-dependent Geometry Deformation for Perceptual Realism. In Proceedings of the 13th Eurographics Symposium on Virtual Environments. 13th Eurographics Symposium on Virtual Environments. Weimar, Deutschland.

Glaeser, G., 2008. Extreme and Subjective Perspectives. Relation, 10(1.38), p.8727.

Groh, R., 2007. Das Interaktions-Bild Theorie und Methodik der Interfacegestaltung, Dresden: TUDpress.

Han, J.Y., 2006. Multi-touch interaction wall. In ACM SIGGRAPH 2006 Emerging technologies. SIGGRAPH \uc0\u8217{}06. New York, NY, USA: ACM.

Hockney, D., 2006. Secret Knowledge: Rediscovering the Lost Techniques of the Old Masters 2nd ed., Thames & Hudson.

Jokela, T. et al., 2003. The standard of user-centered design and the standard definition of usability: analyzing ISO 13407 against ISO 9241-11. In Proceedings of the Latin American conference on Human-computer interaction. p. 53–60.

Ju, W., Lee, B.A. & Klemmer, S.R., 2008. Range: exploring implicit interaction through electronic whiteboard design. In Proceedings of the 2008 ACM conference on Computer supported cooperative work. CSCW \uc0\u8217{}08. New York, NY, USA: ACM, p. 17–26.

Kato, H. & Billinghurst, M., 1999. Marker tracking and hmd calibration for a video-based augmented reality conferencing system. In iwar. p. 85.

Lee, J.C., 2008. Hacking the Nintendo Wii Remote. Pervasive Computing, IEEE, 7(3), pp.39-45.

OpenNI organization, 2010. OpenNI. Available at: http://www.openni.org [Accessed April 1, 2011].

Owen, R. et al., 2005. When it gets more difficult, use both hands: exploring bimanual curve manipulation. In Proceedings of Graphics Interface 2005. Victoria, British Columbia: Canadian Human-Computer Communications Society, pp. 17-24. Available at: http://portal.acm.org/citation.cfm?id=1089508.1089512&coll=GUIDE&dl=ACM&CFID=98535397&CFTOKEN=12659448.

Roberts, J.C., 2007. State of the Art: Coordinated & Multiple Views in Exploratory Visualization. In Fifth International Conference on Coordinated and Multiple Views in Exploratory Visualization (CMV 2007). Fifth International Conference on Coordinated and Multiple Views in Exploratory Visualization (CMV 2007). pp. 61-71.

Schmidt, A., 2000. Implicit human computer interaction through context. Personal and Ubiquitous Computing, 4(2), p.191–199.

Shneiderman, B., 1996. The eyes have it: a task by data type taxonomy for information visualizations. In Proceedings of IEEE Symposium on Visual Languages. IEEE Symposium on Visual Languages. pp. 336-343.

Singh, K., 2002. A Fresh Perspective. Proceedings of Graphics Interface 2002, (May 2002), pp.17-24.

Streitz, N. et al., 2003. Situated interaction with ambient information: Facilitating awareness and communication in ubiquitous work environments. Human-Computer Interaction (HCI International 2003).

Strothotte, T. & Schlechtweg, S., 2002. Non-photorealistic computer graphics: modeling, rendering, and animation, Morgan Kaufmann Pub.

Turk, M.A. & Pentland, A.P., 1991. Face recognition using eigenfaces. In Computer Vision and Pattern Recognition, 1991. Proceedings CVPR'91., IEEE Computer Society Conference on. p. 586–591.

Vogel, D. & Balakrishnan, R., 2004. Interactive public ambient displays: transitioning from implicit to explicit, public to personal, interaction with multiple users. Proceedings of the 17th annual ACM symposium on User interface software and technology, p.137–146.

Ware, C., 2004. Information visualization: perception for design, Morgan Kaufmann.

Ware, W.R., 1914. Modern perspective: a treatise upon the principles and practice of plane and cylindrical perspective, The Macmillan company.

Wojdziak, J., Kammer, D., et al., 2011. BiLL: An Interactive Computer System for Visual Analytics. In EICS 2011 Proceedings of the ACM SIGCHI Symposium on Engineering Interactive Computing Systems. Symposium on Engineering Interactive Computing Systems. In Press - ACM – Association for Computer Machinery.

Wojdziak, J., Zavesky, M., et al., 2011. Figure out perspectives: perceptually realistic avatar visualization. In Proceedings of the IASTED Conference on Computer Graphics and Imaging (CGIM '11). IASTED Conference on Computer Graphics and Imaging.

Yu, J. & McMillan, L., 2004. A framework for multiperspective rendering. Rendering Techniques, p.61–68.

Yuille, A.L., Hallinan, P.W. & Cohen, D.S., 1992. Feature extraction from faces using deformable templates. International journal of computer vision, 8(2), p.99–111.

Zelnik-Manor, L., Peters, G. & Perona, P., 2005. Squaring the Circles in Panoramas. In Tenth IEEE International Conference on Computer Vision (ICCV'05) Volume 1. Tenth IEEE International Conference on Computer Vision (ICCV'05) Volume 1. Beijing, China, pp. 1292-1299. Available at: http://ieeexplore.ieee.org/lpdocs/epic03/wrapper.htm?arnumber=1544869.