Extending the Desktop Workplace by a Portable Virtual Reality System

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Abstract

In this paper we analyse the ergonomic problems of many conventional Virtual Reality Systems. End-user tests have shown that many VR-Systems indicate weak points regarding the posture and projection properties. We describe the features and technical specifications of the newly developed system. For the development we have taken the directives and guidelines from the area of office work with visual displays into account. PI-casso was demonstrated at the HCI 2003, where delegates of the Human Factors and Ergonomics community could use our system. We present the results from a usability questionnaire. We propose the concept of PI-casso, which extends the classic desktop workplace by a compact and mobile Virtual Reality system to be used at office workplaces.

1. Introduction and related work

Powerful Virtual Reality (VR) has been associated up to now with exceptionally expensive high-tech environments, which presents insurmountable obstacles for the everyday use of VR, even if the need and benefit of VR are clearly apparent. Within the European Union project VIEW\(^1\) and the project Sfb 374\(^2\) a VR-System which overcomes those obstacles has been developed: “PI-casso” is representative for the feat of employing VR ergonomically at an office workplace while keeping the costs to a minimum.

Although there is the trend to use standard personal computers and off the shelf projectors to build VR-Systems and also the trend to build systems which are transportable (e.g. peyote’s iTube [1], Barco’s Baron [2] , VRAC’s low-cost system [3], ImmersaDesk [4], Cykloop [5]), PI-casso pursues additional goals. One of the main objectives was to keep workload as low as possible to make the concept able to be used as a permanent post for productive employment at the workplace. Moreover, a quick setup time and a size to fit the dismantled system into a standard car should ascertain mobility.

2. Requirements

Analysis of the user requirements and user-tests in Virtual Environments, which have been conducted during VIEW, highlighted the following problematic issues [6]:

- **Posture:**
  VR-Systems in which users have to stand constantly are not suitable for a long period of use because they cause fatigue. Additionally, they are difficult to integrate into a desktop working place because of the missing support for Keyboard, Mouse, etc. The implemented system should be adjustable in height and inclination.

- **Projection properties:**
  A lot of VR-Systems do not have sufficient brightness to safeguard ergonomic work in an office with ergonomically correct illumination. The colour correctness of DLP, LCD and D-ILA (LCoS) projectors is not satisfactory for design evaluation, especially for dark colours and in particular the colour black. Scattered and reflected light from the screen lead to low contrast. Black appears to be grey. Ghosting (crosstalk between the eyes when projecting two images for stereo vision) should be minimised as much as possible. Most users preferred a higher resolution to a large field of view. Nevertheless the screen should be big enough to display large objects in full scale. When designing our mobile VR-System these requirements were taken into account.

3. Technical Specifications

The mobile system is made up with standard components. It is based on passive stereo projection with two DLP projectors: “Toshiba P5” with a resolution of 1024x768 pixels (figure 1). Because the projectors have a
very flat housing, there is no need for a shift lens to align the projected image. Modestly tilting one projector results in a very low keystone which is not visible on a small screen. We use two linear polarising filters of type “HN38S” with very good polarization characteristics even with blue light and in combination with the infrared filter of type “KG 1 IR” for decreased thermal impact to save the polarization filter’s lifetime.

Figure 1: The rack with two fixed Toshiba P5 projectors

The system is driven by two synchronised Laptops running the VR-Software “Lightning” under Linux. The system uses precise optical tracking with little static and dynamic measuring error, built by “A.R.T.”. Occlusion of reflectors at glasses and input devices can be precluded. The screen is grey and frosted on both sides: “Screen-Tech ST-50Z/3/DC” 75x100x3mm. Laptops are used and the packed system fits into a standard estate car, and thus is portable.

4. Ergonomics

In the project Sfb 374 existing directives and guidelines for ergonomic requirements from the area of office work with visual displays have been investigated [7]. Focus of this research was the applicability of these directives to the situation at Virtual Reality Systems. Accordingly the improvement of ergonomics and usability was one of the main goals, when applying the results to the design of PI-casso.

Working alternating at a Desktop PC and at a VR-Installation is the typical situation a programmer and also a CAD-Designer is confronted with. Repeatedly changing between input devices and glasses, and repeatedly standing up and sitting down when changing the workplace is very demanding and time consuming. With the new concept developed, the user is equipped with an integrated workplace, at which he can simultaneously work in the virtual environment and at a desktop PC. The desk can be used as in common offices for typical activities with the possibility to accommodate a monitor, mouse and keyboard on it (figure 2).

According to the suggestion for an ideal screen inclination in EN ISO 9241 [8] the screen inclination is 16°. Due to its relatively small screen the system features a relatively high resolution in comparison to other far more expensive VR-Systems. Compared to standard desktop monitors the resolution obviously is lower (yet the field of view and therefore the feeling of immersion is higher). The aperture angle of one dot at the eye of the user is 0.0457° horizontal and 0.0454° vertical and therefore reaches 36% of the resolution of the human eye while most existing VR-Systems only reach 23%. Table 1 shows the field of view and the resolution of standard desktop monitors and VR-Systems. The column “rel. Resolution of the Eye” shows, that some desktop monitors already achieve the capability of the human eye, while VR-Systems still lag behind.

Due to its small screen, PI-casso can be used within an office workplace where illumination is should be in the range of 300 to 1000 Lux with a recommended value of 500 Lux [9] whereas for common VR-Systems the room needs to be darkened (to a maximum of 300 Lux.)

PI-casso is also adjustable in height and inclination to suit different percentiles, gender and preferences. It can also be used as a standing workplace. In this way, the workstation can be adapted to suit each user, in much the same way that an average desktop workstation can be adjusted to meet individual needs – a first for a VR projection screen based system.

Figure 2: PI-casso in an office environment
Table 1: List of the field of views and resolutions of VR-Systems in comparison to desktop monitors.

<table>
<thead>
<tr>
<th>Resolution</th>
<th>Dimension Viewing Distance</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>rel. Resolution of the Eye Field of View [%]</td>
</tr>
<tr>
<td>Barco Baron</td>
<td>1200</td>
</tr>
<tr>
<td>PI-casso</td>
<td>1024</td>
</tr>
<tr>
<td>HMD VR V8</td>
<td>640</td>
</tr>
<tr>
<td>15&quot; Dell Laptop</td>
<td>1600</td>
</tr>
<tr>
<td>15&quot; Monitor</td>
<td>1024</td>
</tr>
<tr>
<td>17&quot; Monitor</td>
<td>1200</td>
</tr>
<tr>
<td>19&quot; Monitor</td>
<td>1200</td>
</tr>
<tr>
<td>20&quot; Monitor</td>
<td>1600</td>
</tr>
<tr>
<td>21&quot; Monitor</td>
<td>1600</td>
</tr>
<tr>
<td>22&quot; Monitor</td>
<td>1600</td>
</tr>
</tbody>
</table>

5. Evaluation

5.1 Testing Conditions

As of yet a controlled experiment has not been conducted to test the usability of PI-casso. However, there was a public demonstration of PI-casso at the International Conference of Human Computer Interaction, 2003, in Crete, and this section presents the feedback comments from visitors. This conference and its exhibition was chosen as an appropriate forum for the demonstration of PI-casso as the delegates were predominantly of the Human Factors and Ergonomics community. These delegates were able to provide expert feedback on the design, usability and utility of the system exhibited. Two applications were demonstrated using the PI-casso system.

One application was an immersive modeller, in which the users were able to create geometry and draw within the 3D-space. The users had to use two devices to interact with the VE: the “Dragonfly” and the “Bug” (figure 3) [10]. The Dragonfly was held in the dominant hand and was used for navigation and to make precise movements (e.g. paint, draw, delete, etc.). Since it did not comprise buttons, users had to press buttons on the Bug, which was held in the non-dominant hand. The Bug comprised two buttons. The left button was used for navigation and the right button for selection and manipulation. Additionally the Bug comprised a jog-dial for the menu interaction. Pressing the jog-dial once will open the menu. By turning the jog-dial the user can scroll through the menu. Pressing a second time will select the menu item. In this way using the menu is decoupled from the tracking system. The second application was the visualization of a design model of a Peugeot, derived from CAD. Users were able to navigate through the interior of the car to evaluate design and ergonomics. The lighting conditions, environment colour, etc. could be modified using a menu.

Figure 3: Interaction Devices “Dragonfly and Bug“

Visitors to the exhibition stand were given verbal information about the project and each application, and were then given the opportunity to interact with the Virtual Environments. They completed the feedback form after they had used the demonstrator applications.

5.2 User Feedback

The feedback form required visitors to complete three questions:

1. How do you think the technology demonstrated could be used in your company?
2. How easy did you find the technology to use?
3. Please give any comments on how the technology could be improved.

The results from each of the questions will be presented in turn.

Question 1. How do you think the technology demonstrated could be used in your company?

There were 34 responses to this question. Most participants were positive about using this technology (28/34) whilst some did not think, or were not sure that the technology could be used by their company (6/34).

Suggestions for use of this technology were as follows:

- Design applications – from primary levels to the most complicated, in different sectors (4/34).
- Design for possible assessment of visual impact.
- Human Machine Interaction for designers, manipulation of objects or creative work, engineering review/demonstration.
- Manipulation of 3D objects using the optical interaction device.
- Designing metaphor based mobile phone services.
- Filter technology for VR applications.
- 3D design of shapes – i.e. integrating physical and virtual design of shapes.
- Investigation of hand-eye co-ordination – studying mental representations of 3D objects.
- Training applications
Sales applications, e.g. customers can visualise their future car and choose different design options (2/34).
Interaction device is well designed and could be integrated into existing applications (3/34).
Could use technology to produce portable workstations.
Games.
Visualising auditing environments.
Evaluating prototype models.
Mock up evaluations.
In human factors work.
Teaching applications (3/34).

Question 2. How easy did you find the technology to use?

There were 41 responses to this question. Many participants found that the technology was ‘very easy’ to use (22/41), some participants found that it was not too difficult to use (3/41), one participant commented that he would need some training. Some participants found that the technology was a bit difficult to use at first, but that they learnt how to use it quickly (3/41), a few participants found the technology difficult to use (3/41).

The following comments were made about interaction within the VEs. One participant commented that he found it very easy to learn how to navigate, but found the context menus hard to identify. Another participant found the menu a bit difficult to use. One participant found it awkward to use two hand-held devices within the same application. Another participant commented that the buttons on the input device were not as intuitive as he would have liked, and he was not used to co-ordinating two input devices. Two participants experienced problems with the pointer movement – one commented that the pointer moved a little faster than the hand movement, whereas the other commented that the pointer did not ‘line up’ as expected, leading to some confusion when performing manipulation tasks. One participant found that it took him a while to understand how to use the dragonfly and the menu – he did not realise that he had to press the wheel to select a menu option, however, he enjoyed the interaction and thought that the technology worked well.

One participant found that it was very easy to interact with the environment by making gross movements, however, it was a little more difficult to make precise movements. One participant found that it was difficult to judge whether it was easy to use the technology, however, he found that it was a positive experience. One participant commented that this technology is what he is looking for in his professional work.

Question 3. Please give any comments on how the technology could be improved.

There were 21 responses to this question. Suggested improvements to the applications are listed as follows:

- Enable the functionality of painting from a further distance.
- Make viewing glasses adjustable to head size and distance between the eyes – this may improve the image quality.
- Make the set-up process easier.
- Enable better synchronisation of hand movement and movements of tracking adjustable in the PI-casso demonstrator.
- Use technology in a darker room.
- Use a joystick for navigation.
- Adjustable speed and a larger set of interaction capabilities.
- Menus should be made stationary at a certain screen position when you wish to release the left hand.
- Allow the option to change colours (2/21).
- Use different labels/text.
- Consider configuration with 3D authoring tools.
- Investigate the role of audio.
- Link technology with brain/mind/hand research.
- Employ the use of speech in addition to hand-held input devices.
- The menu should be clearer – the dragging and navigation tools should be integrated into just one virtual object.
- Implement a training package.
- Line up pointer and link or combine the two interaction devices.
- Enforce more restriction on movement so that it becomes more difficult to get lost.

The feedback shows that users were positive about the use of this mobile VR technology. There appear to be some problems with interaction, however, these will be examined in more detail by conducting controlled usability experiments, which will enable us to further refine the devices and interaction techniques employed (see Patel et al., submitted, and [6] for details of how we have previously achieved this).

6. Conclusion

This initial assessment of PI-casso showed that generally users were very positive about the potential of such mobile VR-Systems, and they were able to identify specific applications for its use within their workplaces. There is clearly a need for exploiting the advantages of using VR in a way that is easily accessible to the average company. A mobile system is one step closer to bringing the benefits of VR into the same arena as the office desktop computer.
7. Acknowledgments

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8. References


[7] Sonderforschungsbereich 374: Entwicklung und Erprobung innovativer Produkte -Rapid Prototyping-; Report and Results 2001 – 2003; University of Stuttgart; Speaker: Prof. Dr.-Ing. habil. Prof. e. h. Dr. h. c. H.-J. Bullinger

[8] International Standard DIN EN ISO 9241-1: Ergonomic requirements for office work with visual display terminals (VDTs); Publication date:2002-02

[9] DIN 5035-2: Artificial lighting: recommended values for lighting parameters for indoor and outdoor workspaces; Publication date:1990-09