

# Personal Perspective: Using Modified World Views to Overcome Real-Life Limitations in Virtual Reality

Adrian H. Hoppe\*

Karlsruhe Institute for Technology (KIT)

Florian van de Camp†

Fraunhofer IOSB

Rainer Stiefelhagen‡

Karlsruhe Institute for Technology (KIT)

## ABSTRACT

Virtual Reality opens up new possibilities as it allows to overcome real-life limitations and create novel experiences. While interacting with other people, it is beneficial to share a common view point. We modify the virtual world to allow face-to-face interaction with another person, while still retaining an optimal point of view on presented data. This is done by adapting the virtual environment independently for each user, using translation, rotation and scaling. The presented modification of the world gives a natural solution to the problems of collaborative analysis of content. It is therefore beneficial for usage in human-human interaction scenarios that support cooperative work.

## 1. INTRODUCTION

Virtual Reality (VR) offers many possibilities to view, create and analyze data. Human-Human Interaction (HHI) is very important, since the Virtual Environment (VE) can be shared with others users. But, if the VE is only based on the laws of physics and tries to emulate reality, it wastes potential. New capabilities can be used to enrich HHI. This paper presents the concept of a Personal Perspective in VR (PPVR) for each user. By a modification of the virtual world of each person, every user can have an optimal point of view on the respective content. At the same time, each can also remain at an ideal position in relation to the other collaborators in order to communicate with them. For example, all users around a table can have an upright view on a shared text, a video or a map while at the same time they see gestures of the others in front of them.

## 2. RELATED WORK

There is lots of work done in the field of collaborative virtual and tabletop environments. We focus in this section on the most related work. Collaboration increases task performance [1], but collaborative understanding is negatively affected by ambiguous information and different roles or expertise of group members [5]. Different users need a mutual understanding of the virtual world and therefore need to build a common mental representation [6]. It takes time to take the mental representation of the other party into account, which varies with the degree of rotation. Some systems personalize the displayed content per user [2–4]. However, few focus on the adaptation of the avatar to retain non-verbal cues, like gaze, which are very important [7]. PPVR resolves the disadvantages of an inconsistent world view by adapting the user’s tools and avatar accordingly and sustains the advantages of a personalized perspective.

\*e-mail: adrian.hoppe@kit.edu

†e-mail: florian.vandecamp@iosb.fraunhofer.de

‡e-mail: rainer.stiefelhagen@kit.edu



Figure 1: PPVR of the user on the bottom. Note: Green content is only visible to the bottom user and gray-striped content is only visible to the top user. Left: real-life view, table content is inverted. Center: Rotated content, but indicated position is wrong. Right: Rotated content with modified avatar and indication, correct location is marked.

## 3. WORLD MODIFICATION FOR A PERSONAL PERSPECTIVE

VR allows to transform virtual content per user, e.g. rotating a map on a table (see Fig. 1). However, the world modification leads to an inconsistency between the users. Pointing gestures and the head orientation or focal point of a user need to be corrected. Therefore, a solution is presented that retains user’s gestures and intent. This paper focuses on 2D information displayed on a table but the following modifications can also be applied to 3D data. For the transformation of the object into the personal view of the local user  $A$ , a  $4 \times 4$  matrix  $U_A$  is applied.  $U$  can contain translation, rotation and scaling and alters the world of each user to his or her requirements respectively. Translated content would allow two users to stand side by side, but right in front of the same object. Rotation allows users to see identical aligned content from different stand points, like rotated content on a table. And scaling would allow them to work on differently sized objects, e.g. scaled down for better overview or scaled up for more visibility. A location in the world of an arbitrary user  $A$ , e.g. his or her laser pointer indication, can be transformed to the VE of any other user  $B$  using the following two formulas:

$$\mathbf{x}_l = U_A^{-1} * M_O^{-1} * \mathbf{x}_i = (M_O * U_A)^{-1} * \mathbf{x}_i \quad (1)$$

where  $\mathbf{x}_i$  is the world position that user  $A$  indicates in his VE.  $M_O^{-1}$  is the inverted model matrix of object  $O$  and transforms a location from world space into local space.  $U_A^{-1}$  reverses the local perspective modification of user  $A$ . As a result,  $\mathbf{x}_l$  is the unmodified location in the local space of  $O$ . In  $B$ ’s world the location now needs to be modified:

$$\mathbf{x}_m = M_O * U_B * \mathbf{x}_l \quad (2)$$

$\mathbf{x}_m$  is the resulting modified position in the world space of user  $B$ . The two equations can also be used to transform the user’s avatar. For this, locations in the forward and up direction of the head and hands of  $A$  are transformed into the personal perspective of  $B$ . The head and hands of  $A$ ’s avatar in  $B$ ’s world can then be rotated to face the transformed points accordingly.

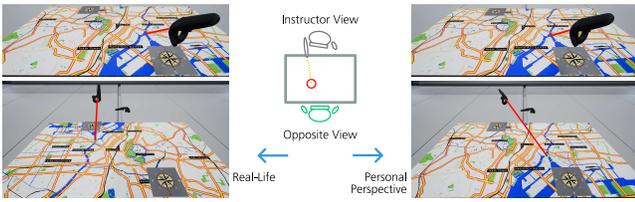


Figure 2: Comparison of real-life and PPVR viewpoints on a table. In the real-life case, the table content is upside down for the user on the opposite side of the table. With applied modifications, both users can see the content upright in the personal perspective case.

#### 4. EVALUATION

To test the proposed modifications for a PPVR and to compare them to an unmodified environment, a user study with 16 participants (13 male and 3 female, age of  $\bar{O} 32.4 \pm 11.0$  years) was conducted. On a scale from 0 to 4 with 0 being none and 4 being very high, the experience of the participants is  $\bar{O} 1.5 \pm 1.2$  with VR and  $\bar{O} 2.8 \pm 1.2$  with maps. For VR hardware, two HTC Vive were used. The avatar of the users is very basic and only shows the HMD and the two controllers. Subjects shared a VE with a test supervisor that stood on the other side of a table. The subjects were asked questions regarding locations and path finding about a map that was displayed on the table's surface. Once, with a real-life replication where the test supervisor had a north oriented map and the subject saw the map upside down. The other time, the map was north oriented for both users and the personal perspective modifications were applied. Prior to each test users learned the interactions and accustomed themselves with a training task. Figure 2 shows the in-game views of the users with the two map orientations. To eliminate training or fatigue effects in the collective evaluation, the order of the setups was mixed. Furthermore two different maps were used. During the user study, qualitative and quantitative data was collected. After each of the two tasks, users were prompted with a NASA RAW-TLX questionnaire. Additionally, users were asked how natural the conversation with the test supervisor felt and how much they depended on a compass while orienting themselves on the map. Users rated the different questions on a five-point Likert scale ranging from low (0) to high (4). Besides the questionnaire, the performance of the users is quantified with time and error measurements (see Fig. 3). Overall, only five errors were made with the upside down table and one error with the modified PPVR table. During the upside down map tests, however, users often switched answers 'west.. no, I mean east', which in return also explains the higher response times. A final questionnaire asked how well users could solve the tasks together with the test supervisor. The result is  $\bar{O} 3.9 \pm 0.3$  on a scale from 0 (very bad) to 4 (very good). The question, if they could solve the map tasks better with the north oriented map than with the upside down map from 0 (No, not at all) to 4 (Yes, totally) was answered with  $\bar{O} 3.2 \pm 1.2$ .

#### 5. CONCLUSION

The work of this paper is focused on a modification of the VE which gives users the possibility to share a common viewpoint. The proposed method allows the personal adaptation of content for any number of users through translation, rotation and scaling. Resulting world inconsistencies are removed through an adaptation of the user's avatars and tools. The advantages of a personal perspective are verified through a user study. By rotating the content on a table it is possible

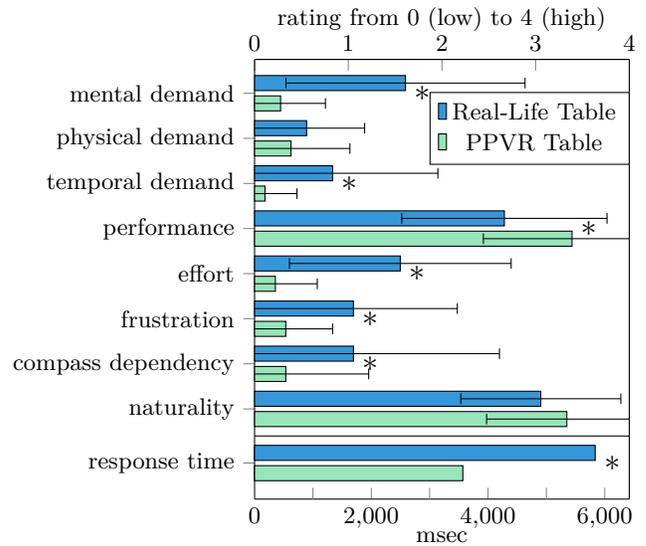


Figure 3: Results as average value with standard deviation error bars. Asterisks indicate statistical significance ( $p < 0.05$ ).

for two (or even more) users to review data or execute a task presented to them from a mutual perspective. The introduced method transforms indicated positions into the different perspectives of the respective users. Further modification of the user's avatar via rotation of the point of attention and hand orientation results in a mostly undisturbed human-human interaction. Executing tasks in an upright or familiar perspective reduces mental load and increases task performance. For future work, we aim to transfer the proposed technique to a full-body avatar.

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