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Classification of VR interaction techniques, based on user intention

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Abstract

The number of different virtual reality (VR) systems and corresponding interaction techniques is quite manifold, today. For dedicated input devices, data types and application domains specific interaction techniques have been developed. Thereby a wide audience of researchers can benefit from using VR systems. A drawback is, that for non-VR specialists it is nearly impossible to get a clear overview and identify proper interaction techniques for their research questions. Therefore this article proposes a classification scheme for VR interaction techniques based on the users' purpose. This will help non-VR specialist to identify VR systems and interaction techniques perfectly matching their demand. The classification will be used within the project VISIONAIR to bring together VR experts and external users.

Categories and Subject Descriptors (according to ACM CCS): I3.6 [Computer Graphics]: Methodology and Techniques—Interaction techniques

1. Introduction

Interaction in virtual reality (VR) is a crucial aspect that needs to be provided according to the users' needs to allow the beneficial usage of VR systems [MYW*12]. The better the interaction technique reflects the users' interaction demand, the higher efficiency and effectiveness during the usage of VR systems can be achieved [Bux86]. Therefore an approach to classify interaction techniques in VR against the users' needs is introduced in this paper.

The goal of this paper is to analyse and assess the supportive potential of interaction techniques for the interaction within virtual environments. The investigation will result in a kind of recommendation list for researchers so they can identify the interaction technique which suits their demands best. By offering such a list, even non-VR experts will have the opportunity to understand the characteristics of different interaction techniques and compare them considering the requirements of their own research projects.

A classification scheme has been developed which is based on the user requirements. Thereby the intention of the user (Why to use the VR system?) and his targeted purpose (Which objective should be achieved using the VR system?) are the central points which influence the classification. This should facilitate the proper assignment of user demands and interaction techniques later on. By categorizing the intention behind the interaction techniques, users may choose best which interaction technique they request to support their research. The classification scheme can be understood as a common requirement specification that connects user demands and capabilities provided by certain interaction techniques.

Moreover, due to today's fast technology progress previous classifications are stressed to their limit. In particular, connected portable devices, coming in different sizes, possessing significant computing power. They are input and output devices in one, thus they allow many types of applications with completely new characteristics. So a purely technical oriented approach can be too restrictive for the definition of new services and interaction techniques in VR applications.

The VISIONAIR project analyses and assesses the supportive potential of interaction techniques for the interaction

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within immersive, virtual environments. VISIONAIR's perspective is oriented on the benefit that can be created by the end-user which is utilizing the interaction techniques to conduct research in different domains. Hence providing interaction techniques can be understood as a kind of service offered to clients. Within the project the focus is especially laid on the development and beneficial use of handheld devices in VR.

2. Related work

'An interaction technique is the fusion of input and output, consisting of all software and hardware elements, that provides a way for the user to accomplish a task [Tuc04].' Thereby interaction techniques fulfil a certain user demand occurring from interaction tasks by using input and output devices in a beneficial way. Users are enabled to perform a specific task within software systems (e.g. a VR system) serving their objectives [Bea00] [DF04]. To classify interaction techniques some research work has been carried out [Bow99] [CB02]. The objective is to categorize interaction techniques to get an overview on available techniques and identify gaps to initiate new design projects. In these two approaches, either the perspective from immersive VR [Bow99] or the end-user perspective [CB02] are more or less separately addressed. A combination of both approaches, necessary to classify VR interaction techniques from the end-user's point of view-seems to be missing .

In [Bow99] interaction techniques are classified according to a relative low technically oriented level, decomposing interaction techniques into elementary fractions . Three main categories have been identified, which cover more or less the whole set of interaction in VR. By distinguishing (1) travel, (2) selection and (3) manipulation user's input towards the VR is captured quite generically. The classification is completed by the category (4) system control which includes superior functionality that is not directly related to the user interaction in VR, but requested to operate the VR systems in general.

Following [NBS12] VR interaction has to address the users' wish to handle virtual objects commonly in 3D as if they were real. This demand can be broken down into three requirements interaction techniques must fulfil in the scope of immersive VR systems.

- The dimension of space handled can range from 1D to 3D
- The degree of freedom (dof) devices allow is usually 2dof to 6 dof
- Devices and interaction techniques usually provide complex feedback to the user [NBS12]

In contrary to this technical focused approach is the classification scheme developed by [CB02] is not exclusively addressing VR interaction techniques, but shifting the focus to the information and content aspects of interaction. The main classification criteria (Figure 1) are directly connected to the users' behaviour and their intention beyond the interaction technique.

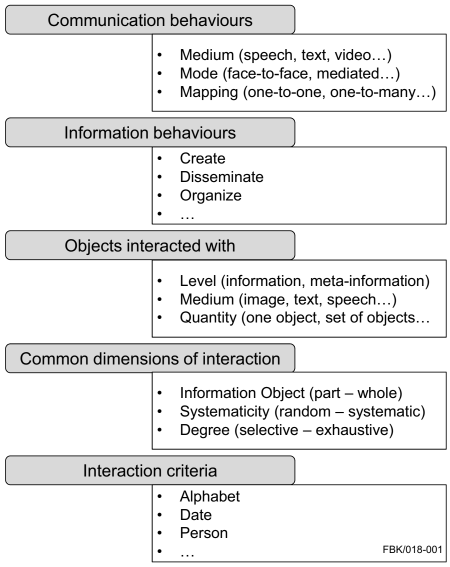

Figure 1: *Facets of a classification of interactions [CB02]*

Even if the approach introduced in [CB02] is less technical, and more information-oriented the literature review revealed that a classification approach to categorize and describe VR interaction techniques from the end-user point of view is missing. This gap shall be closed by the approach presented in this paper.

3. Classification Approach

Within the VISIONAIR project, multiple research institutes are connected, operating a wide range of different visualization facilities, targeting at highly diverse research domains. Hence the following approach summarizes the experience gathered by the usage of many different interaction techniques. The developed classification scheme is structured into three main classes 'purpose, 'object medium' and 'user'. Each main-class contains one sub-class that specifies the main-class more in detail (Figure 2). The objective of this structure is to classify VR interaction techniques from a generic, user driven, perspective incorporating the intention of the end-user as a major driver. According to each main-class a sub-class is defined, to outline the core functionality of the main-class. Detailing out the description of the 'purpose' the user wants to achieve, the sub-class 'feedback' is defined. Feedback channels are often essential for the usability and utility of interaction techniques from a user's perspective. By providing feedback on the interaction, the user gets direct indication whether the tasks beyond the interaction can be achieved. As second main-class, the 'object medium', which is handled by the interaction technique, is defined. Thereby

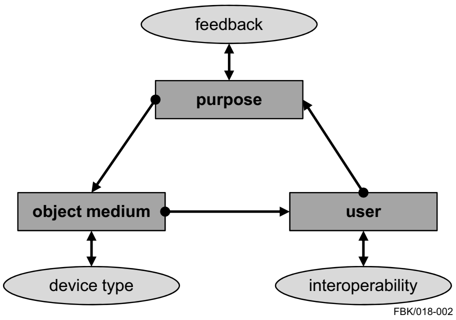

Figure 2: *Main-classes of the classification approach*

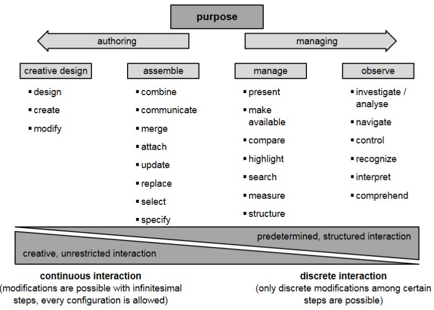

Figure 3: *Attributes of the main-class 'purpose'*

the characteristics of information processed are the main focus (e.g. dimension of visual objects). The fact that, for some interaction techniques, specific device types are required will be considered subsequently by the sub-class 'device type'. Thereby, it is not the device specifications in detail (e.g. vendor) that are mentioned. Rather the capabilities provided are in focus (e.g. degrees of freedom).

As last class the 'user' involvement is considered. Here the working situation and the team-constellation for which the VR interaction technique is used will be reflected. The sub-class 'interoperability' is outlining interconnections which are required and established by the interaction technique. Thereby interconnections between users, information, and also between several interaction techniques are considered.

Each main-class and each sub-class are detailed out by a set of attributes, differentiating the characteristics of the classes. This will be further illustrated by the description of the main-class 'purpose', as this class is the core classification measure of the approach. Based on the idea that interaction techniques are chosen due to the functionality they provide, 'purpose' is characterized by the level of creative or predetermined interaction capabilities provided. Interaction techniques which allow an independent interaction are separated from interaction techniques allowing the interaction only for predetermined tasks. Independent interaction is characterized as some kind of continuous interaction that allows modifications of the virtual environment within infinitesimal steps where every configuration of virtual elements is allowed. In contrary, interaction for predetermined tasks can be understood as some kind of discrete interaction where only discrete modifications among certain steps are possible. As shown in Figure 3 four attribute categories are proposed which outline the classification criteria and subdivide the main-class 'purpose'.

The four attribute categories, named 'creative design', 'assemble', 'manage' and 'observe' are regiment into the continuum of continuous and discrete interactions. They are each composed out of several typical tasks which are the purpose behind certain interaction techniques. These attributes will be the level on which users and interaction experts classify interaction techniques and user requirements on a generic base. They shall help users to better identify the interaction capability they request. For the other main-classes and subsequently the sub-classes detailed attribute descriptions are made accordingly.

4. Implementation of the classification scheme

The classification scheme is by now implemented in an MS Excel based taxonomy which integrates the classes into a structured and clear table. The generic table will be completed by instances, describing the concrete interaction techniques used by VISIONAIR Partners. After setting up a full list of interaction technique descriptions, the classification scheme shall be published online, to be available for non-VR experts. So the knowledge among interaction techniques for VR systems and the classification taxonomy can be distributed. The table is structured by three hierarchical stages containing all main-classes, sub-classes and attributes of characteristics, according to the structure of the classification scheme (Figure 4).

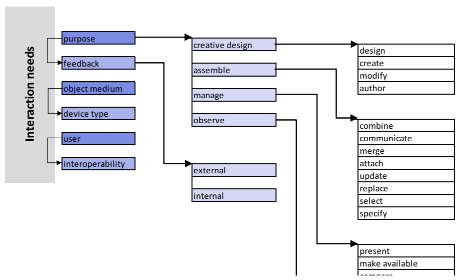

Figure 4: *Hierarchical structure of the classification scheme in MS Excel*

In addition to the generic taxonomy, descriptions of interaction techniques developed and used in VISIONAIR are included in the MS Excel file. Therefore the list of generic attributes is instantiated once for each interaction technique. Further, a short prosaic description is added to each interaction technique, describing the idea behind the interaction

technique and special characteristics among the usage. By this a comprehensive list of interaction techniques used and developed by VISIONAIR Partners for various purposes is established.
The implementation of the classification scheme allows the comparison of interaction techniques, but also the identification of interaction techniques matching specific user demands. As analysis tool a comparison algorithm between given user needs and the interaction techniques outlined in the list is implemented. Users have the option to mark all requested functionality based on the generic taxonomy and the algorithm is identifying the interaction technique that fits the demand best. So even non-VR experts have the ability to search for beneficial ways of interacting with their given research data.

5. Examples of actions conducted in Visionair

In the Visionair framework, we conducted a common task, consisting in analyzing the supportive potential of interaction techniques within virtual environments. As evoked above, the main objective was to help expert as well as new users of VR systems in choosing the best suiting interaction technique regarding their demand. Following two example interaction techniques are outlined and the classifiaction scheme is used on them. This will illsutrate how classification will be done to adress end-user perspective. In this domain, Handheld Devices are more and more used (being relatively cheap and portable) to support users while working with VR systems. 2D-based interaction devices in 3D environments offers new potentials, but also challenges which need to be tackled. Different partners of Visionair made intensive analysis and investigation on the interaction techniques already used. Extensions towards the integration of Tablet PCs, tangible interaction devices and device-free interaction were conducted. Among the different experimental studies that have been carried out in the recent period, we can cite a few. First, specific comparisons between 3D interaction and 2D interaction techniques have been carried out [NBS12]. Such analysis has been specifically used in the context of manufacturing systems [SMN12]. A similar approach consisted in investigating gesture- and tool-based interaction in virtual environments [WMA13]. PC and/or Android tablets were used considered, for interacting with a CAVE system or in generic docking tasks [MP14].Gesture- and tool-based interaction techniques were also compared in the context of 3d sketching [IS12].

To illustrate how the classification scheme will handle the characterisation of a concrete interaction technique, an example is given following. The interaction technique called 'wind back and forwards' uses a Tablet-PC to control animations and predefined model movement in a CAVE by directly influencing the progress of the animation. Therefore a slider is used to control the runtime of an animation or model movement (Figure 5). By visualizing such a progress bar on a Tablet-PC, a user can tangibly control certain animations, while being in a CAVE and using other navigation techniques in addition. The virtual sliders gives direct feedback among the current frame of the animation, which makes the Tablet-PC an output device in parallel. In addition visual feedback is provided by the VR system on which the virtual environment is implemented. At the University of Kaiserslautern the interaction technique is realized by a Tablet-PC on which the 2D GUI 'Covise TabletUI' is implemented.
This prosaic description of the interaction technique gives a

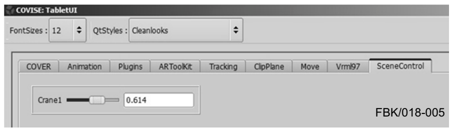

Figure 5: *Example of the interaction technique implemented with Covise TabletUI*

first impression of the capabilities and characteristics of the interaction technique 'wind back and forwards'. Following the interaction technique is sort into the classification scheme (Figure 6). Looking at the purpose users can achieve by using 'wind back and forwards' it is obvious that the interaction technique is no very flexible and creative during the usage. The objects handled and the targeted animations need to be predefined, hence observation is the major 'purpose' attribute which is addressed. The metaphor enables to control animations of 2D and 3D models. Even if the potential movement and modifications controlled by the interaction technique take place in 2D and 3D, the interaction on the Tablet-PC itself has only 1 degree of freedom, which makes interaction very accurate. The Tablet-PC can be handled by one person at a time, which has than the opportunity to operate the animation and investigate effects and independencies with other elements in the virtual environment.
An example application realized at the University of Kaiserslautern is the rotation of cranes in a factory layout (Figure 7). Thereby the user can control the crane rotation and assess the covered area the crane is able to operate in. The user has the opportunity to check the position of cranes and to compare the realized performance in context with the design of certain workplace layouts.
Another example describes a creative modelling technique, namely immersive '3d sketching'. The technique is used to draw three-dimensional strokes within a virtual scene (i.e. interaction purpose creative design, design, create). The immersive sketching system runs in an immersive five-sided CAVE with 2.5 m edge length, employing a rendering cluster and an optical tracking system. It allows free-hand drawing and modelling in one-to-one scale (object medium; 3-dimensional; 3D models) by means of tangible interfaces, e.g. a stylus or bi-manual modelling tools (Figure 8) [IWMS09]. The stylus allowed drawing virtual ink directly into the virtual environment, following the movements of the

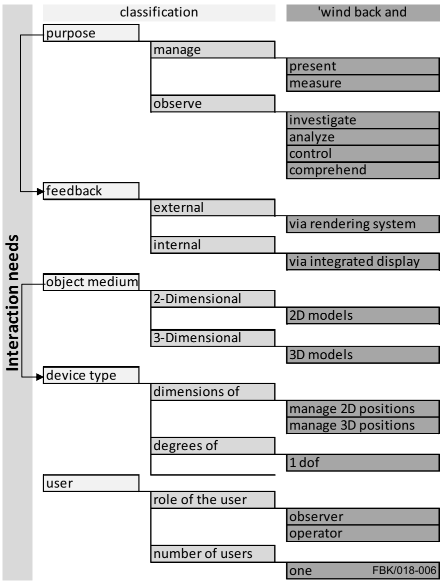

Figure 6: *Exemplary classification of the interaction technique 'wind back and forwards'*

Figure 7: *Analysis of the area covered by a virtual crane within a factory layout*

stylus tip (device type; degrees of freedom; 6 dof). A toggle-button inside the stylus is used to start and stop the extrusion of virtual ink at the position of the tool tip (observe). The system was evaluated in various previous user studies e.g. in terms of usability and learnability. It could be shown that designers are able to learn 3d drawing movements but demand refinement methods [IWMS09] [WIMB10].

This interaction technique was implemented at Fraunhofer IPK Berlin. The user can draw as many strokes as she or he likes (user; role of the user; manipulate). The strokes can be arranged by using a manipulation tool. Strokes can also be grasped with the pen and extruded along the users hand movements as long as the button is pressed in extrusion mode.

Figure 8: *Stylus tool for immersive sketching.*

As the user can simultaneously sketch and walk (navigate) through the CAVE, the system also allows for parallel activities. According to the classification scheme the interaction technique can be described in a standardized way(Figure 9). This description can be further used by end-users to identify the interaction technique which is solving the requested functionality in best way.

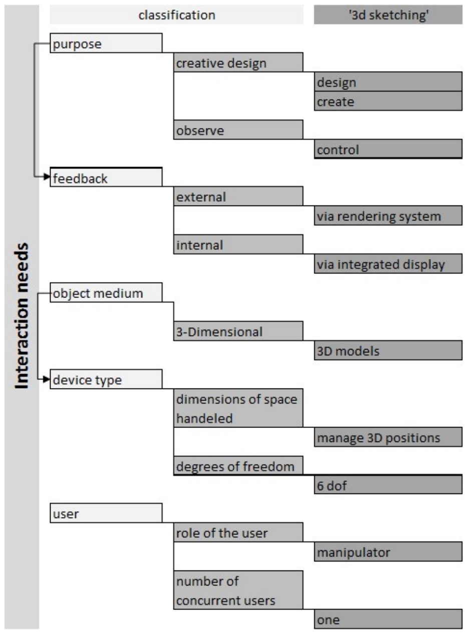

Figure 9: *Exemplary classification of the interaction technique '3d sketching'*

The two example classifications show the theoretically appropriability of the developed classification scheme. For further evaluation a wider database of interaction techniques implemented within the Viaionair project will be build up. Investigations will be made to which extend end-users could profit from the classification scheme as it is proposed by now. The classification scheme can be one part within an innovative knowledge provision framework to allow non-VR experts access to interaction technique know-how.

6. Conclusion and Outlook

By implementing this classification scheme two objectives can be achieved. First existing and established interaction techniques can be classified on a generic base. This allows the comparison of interaction techniques independent from application and VR system. Further assessment of similar interaction techniques on joint applications and problem definitions can be considered. The second objective is that non-VR experts can use the classification scheme to express their requirements in a standardized and structured way. This will help to identify established interaction techniques users request to solve their research questions in VR.
In addition this process can even reveal gaps in VR interaction support. If users specify their requirements among interaction techniques and didn't succeed in finding the proper interaction technique, new research activities can be initiated to develop new interaction techniques according to users' needs. As next step the classification scheme and the comparison algorithm shall be implemented within the VISIONAIR website. This will allow external users to browse through the interaction techniques provided by VISIONAIR and identify beneficial interaction techniques to support their research.

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