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Design in context of use: An experiment with a multi-view and multi-representation system for collaborative design

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ABSTRACT

The current trend of product design leads to a change in the collaborative working style. To find the most efficient way to exchange information on the digital mock-up of a product, a synchronous co-located collaborative design environment with recent technologies is in needed. A new groupware of multi-view system allows multiple users to have individual visual information of a domain-specific representation of digital mock-up. In this paper, we propose a case study for the development and testing of a co-located multi-view system in collaborative virtual reality, aiming at enhancing the multidisciplinary early collaborative design. An ergonomic method of Personas is introduced to the evaluation of the tool, considering various user performance. With a multidisciplinary mug design scenario, experiments are presented, validating the benefits of the proposed system.

1. Introduction

Designing is a complex activity, and failure of support can be expensive in terms of time, people and money and can have a large effect on practice [1]. For years, rapid product development (RPD) is relying on the use of new knowledge-based systems such as haptic systems and virtual reality (VR) [2]. There is an increasingly strong need for immersive visualization and interactive tools that may be used in industrial applications [3]. Recent developments in the use of multi-view technologies allow multiple point-of-views and multiple representations of an object. More precisely, with the development of computer–human interaction (CHI) and VR technology, the approach of displaying multi-representation of a digital mock-up (DMU) through a multi-view system can be used in product design. Moreover, concurrent engineering has changed design habit from traditional sequential engineering to a parallel mode to reduce the overall product development time [4]. In the early stages of design, stakeholders involved tend to propose a collaborative tool that is suited to the concurrent design style [5]. Finally, prospective ergonomics is nowadays a key factor in innovation, of prior importance in product design, lifecycle and especially in its use [6–8]. Thus, extracted motivations for this paper are:

- To simulate virtual product design situations with a multi-view system and prove the efficiency of the method.
- To mix ergonomics analysis and early product design on an industrial use-case to validate the proposed method.
- To validate the multi-view system on a use-case and measure the benefits the design team could have when using this technology applies in the consumer goods industry.

Using design research methodology (DRM) approach [1], the following descriptive study is aimed at understanding collaborative design with multi-point-of-view. We follow a comprehensive descriptive study, which involves a literature review and an empirical study. After reviewing the literature of multi-view systems in industry, we determine our research focus (Section 2). Then, we develop our research plan based on a multi-view system for early collaborative design (Section 3) and undertake an empirical study to evaluate it (Section 4). Finally, the results are then discussed (Section 5) before drawing overall conclusions.

2. Review of the literature

The literature on the use of multi-view is to be discussed here first with the definition of multi-view system, followed by the general applications in the field of virtual reality and multi-representation display. We focus then on an introduction of Personas method and an innovative future collaboration style in early design through multi-view system.

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2.1. Multi-view system

The traditional computer supported collaborative design is basically based on several mono-view systems for communication in distance and special software platforms for product information sharing in client/server mode [9–11]. However, multi-view system is a co-located and simultaneous solution of sharing information and working collaboratively.

Multi-view system is a visual–perception interface which allows humans to see simultaneously multiple images through a unique shared medium. The mechanism of multi-view system is: several images are emitted simultaneously from the display medium and then received respectively by human vision, as shown in Fig. 1. In [12,13], multiple views are described as frames with view-dependent pixels. These views can be displayed as an output package simultaneously. To create multi-view system, various technologies exist in the literature and they are classified into three modes: passive, active, and automatic.

2.1.1. Passive mode

The emitted images are projected in the different subspaces of colorimetry or polarization of light through passive filters. Anaglyph images are created by putting images in different anaglyphic color channels, then these images can be seen separately with red/cyan filters. Polarizing filters restrict the light in opposite vibration directions before projection. Using suitable receiving filters for each corresponding projecting filter, images can be encoded with a separation.

2.1.2. Active mode

Within a very short period, images are actively displayed one after the other in sequence. The mechanism is to synchronize the emitter and the receiver. E.g. shutter glasses, which is a receiver, can change the transparency alternately, synchronizing with the refresh rate of the emitter, which is usually from a projector or a screen. As known in human visual system (HVS), 60 Hz is the lowest frequency for human to have a reflection of continuous images without flick fusion [13]. Modern optoelectronic displays with their supporting receiving devices can operate much higher refresh rates, thus multiple views more than two can be created [13]. E.g. a 120 Hz projector and the supporting shutter glasses can create two views in sequence that each has a 1/120 s period.

2.1.3. Automatic mode

Automatic mode does not need any equipment (e.g. Glasses) at image reception. Images can be seen separately from different positions in spatial dimension beyond the same screen. E.g. A display is placed behind a parallax-barrier, which is an opaque sheet with patterned holes stamped out of it, or behind a lenticular sheet, which is composed by an array of magnifying lenses. Light from an individual pixel in the display is visible only from a narrow range of viewing angles. Thus, the images seen through each hole or lens will change according to vision spots [12]. With advanced screen technologies, multiple spatial views more than two can be realized and the combination of the mechanisms above can produce the system with even more views [14].

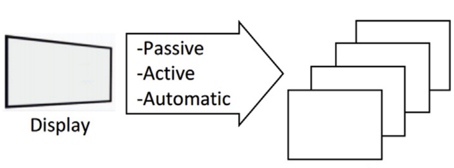

Fig. 1. The mechanism of multi-view.

2.2. Multi-view applications

The applications of multi-view can be categorized into two aspects: multiple point-of-views in VR and multiple representations.

2.2.1. Multi-view in VR

A point-of-view (POV) of an object is generated from a certain spatial position, e.g. in Fig. 2, a DMU of an airplane has several POVs seen from different space positions. Multi-view system can be applied to display the multiple POVs of an object, especially when these multiple POVs are used to create the feeling of stereoscopy in VR.

Becoming a new way for visualization and interaction, VR is widely used in product design and manufacturing, especially in automotive industry [15,16]. This virtual prototype of the product can help evaluate its design by simulating the usage (driving), manufacturing (assembly), etc. Compared to the activities using physical prototype, VR may help in saving time and cost.

To transfer a 3D virtual world to computer graphics, 2D images are calculated as snapshots of 3D world according to a point of view. Binocular vision is natural for humans. For each eye, visualizing from a 3D world is like taking snapshots. The human brain can merge the two snapshots taken from the two eyes to create stereoscopic representation.

Thus, any VR device for creating 3D images belongs to multi-view systems. The three mechanisms of multi-view system also work with VR devices, e.g. passive or active mode multi-view system: 3D glasses, including anaglyph, polarized [17–19], and shutter glasses [20]. In a two-user VR application [15] or a multi-view table [18], the multi-view system, a combination of passive mode and active mode, has 4 POVs for four eyes. Autostereoscopic displays [12,21] also work as an automatic mode multi-view system to receive two POVs for each eye following different spatial positions of the eyes.

2.2.2. Multiple representations

In addition to showing multiple POVs, multi-view system is used to displaying multiple representations. A representation is a perception of an object. People have different representations of an object and they make statements to influence the opinions or actions of others. The users of a multi-representation application choose the representations according to their different roles, different interests, and different preferences. In engineering design shown in Fig. 2, an airplane DMU is a package of data of all the

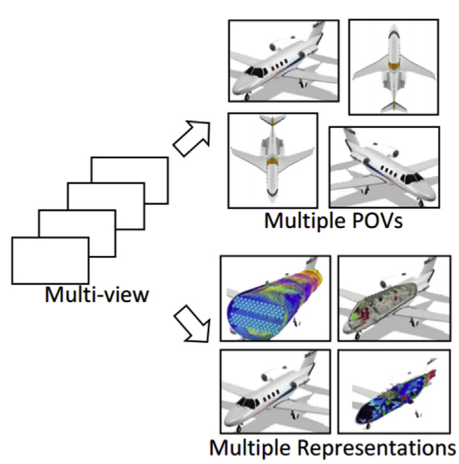

Fig. 2. The applications of multi-view: multi-POV (space transforms of DMU) and multi-representation (domain data of DMU).