Mixed reality mockups for multimodal evaluation of product prototypes

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Abstract: In the process of industrial product development, there is a constant need for prototypes representing the current state of development. Since the manufacturing of physical prototypes is very cost-intensive, virtual prototypes gain more and more importance. Moving from a 2.5D screen visualization to a 3D virtual reality visualization (e.g. in a CAVE) offers a better spatial impression and the possibility of visualizations in a 1:1 scale. However, those virtual prototypes cannot be a complete replacement for physical ones because of their exclusively visual nature which does not allow the evaluation of non-visual features like weight and inertia.
We propose using mixed reality (MR) technologies to serve as a bridge between virtuality and reality, combining the advantages of both worlds. These functional and intuitively usable prototypes enable the designer to find flaws in the concept and allow the inclusion of customer-feedback and usability tests in early development phases.

1 Introduction

The development of industrial products is a complex process. Starting point is usually a problem which is then transformed into a formal description of the design-task. From there, the problem is subdivided into subproblems for which possible solutions are gathered. In order to find the best fitting solution for the initial problem, the solutions of the subproblems and their combinations have to be evaluated. In many situations, this evaluation can only accomplished by building prototypes. This is especially true for mechatronic products, which combine mechanics, electronics and information technology. In this case, engineers and designers from different fields have to work together and need a common discussion-foundation in form of a prototype.

Depending on the current state of the design process, prototypes are also used to test the interplay of the components, to evaluate the design and for function- and usability-test. Due to the high costs and time consuming process of building physical prototypes, the industry increasingly uses virtual prototypes.

The Digital Mock-Up (DMU) technique is widely used for static form-based evaluations, such as assembly/disassembly and collision tests. In addition to that, Functional Digital Mock-Ups (FMU) allow the evaluation of product functionalities and integrate simulation techniques like finite element methods (FEM) into the virtual prototype.

In combination with these techniques, virtual reality technologies can be utilized to gain a better spatial understanding and can help evaluating ergonomic and aesthetic properties. Also, they allow presentations to customers or the management, who are not familiar with the 2.5D representation used by engineers and designers. Another advantage is the enhancement of collaborative work and creative problem solving.

The major shortcoming of these technologies is that they merely provide a visual impression of the product. Other senses are usually not addressed. This makes it impossible to experience non-visual product properties such as weight and inertia. Furthermore, the lack of intuitive interaction possibilities constrains their usefulness and eliminates the possibility of usability test in this early product development state.

Due to these facts, increasing effort is made to integrate physical elements into the virtual environment.

2 Integrating physical elements into the virtual environment

A common approach to integrate haptic feedback into virtual reality environments is the use of force feedback devices. Those mostly have the form of ‘robot-arms’ with a stylus at the end, the user can interact with. The problem is that they are practically not usable in immersive VR-environments because of their immobility and the limitations in freedom of motion. Moreover, to avoid occlusion-problems, action- and perception-space are usually separated. Also, they fail to provide touch-feedback and grapsability of the virtual prototype. Krause et al. addressed the latter problem by mounting a physical part to such a device [Kr05].

Some research has been done, introducing augmented reality techniques into the field of product development. Lee and Park proposed and implemented augmented foam-models. They used head mounted displays (HMD) and visual markers to overlay a foam-mockup with computer graphics [LP05]. This approach provides rapid production of touch- and graspable prototypes. Park et al. proposed tangible prototypes using rapid prototyping models and an optically tracked pointer for interaction [Pa08].

Both researches focus on small handheld products, making it possible, to build a mockup of the complete prototype using CNC or additive manufacturing methods. They can only partly be adopted for products where only a part of the product can be physically built because of size and complexity (e.g. cars). Furthermore, mainly formal aspects of the product are addressed, rather than functional ones.

3 Research Focus

The main focus of our research is the multimodal experience of virtual prototypes. The idea is to use mixed reality techniques to accomplish this.

The research questions are: Which parts of the prototype have to be physical, which can be digital? What's the best way to integrate the digital information with physical parts of the prototype? Which techniques should be utilized? Which forms of interaction is appropriate for a realistic product experience? How can the occlusion problem be overcome, that always emerges when combining physical and virtual objects.

Furthermore, the integration of this novel prototyping-approach into the design-process and the inclusion of techniques like hardware-in-the-loop simulation is addressed.

References

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