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USE SCENARIOS FOR DIGITAL DESIGN STUDIOS OF THE FUTURE, FIRST SUBMISSION

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ABSTRACT
This paper presents the results of an explorative study concerning the possible use and development of scenarios for future digital design studios. Although it is difficult to forecast the future, these systems will probably include both the currently available and emerging next generation design support tools and interaction technologies. The goal of our background research has been to study the relationships between the human and application demands and the affordances of new technologies. We investigated the wishes of designers and design companies through discussions, creative sessions and a questionnaire. We analyzed the trends of technology development and range of functional affordances. We concluded that the main designers' objectives with regard to advanced design support are to have sufficient support for inspiration, visualization and validation. Based on these fundamental demands, we developed three different use scenarios for future digital design studios. These scenarios have been tested with potential users. This showed that the scenarios indicate possible directions for further research, communicate possible solutions, and inspire designers in product development.

Keywords: Digital design studio, use scenarios, advanced design support, sensing technologies, volumetric visualization, multi-sensational feedback

1 INTRODUCTION
Computer Aided Design (CAD) systems are now commonly used by designers. CAD software can significantly support designers during detailed design, allowing precise modeling, realistic rendering and interfacing with various types of validation software. Modeling in CAD systems asks for a structural approach to define forms. In the early phases of the design process, the designer cannot fully define the morphological features and form of the product to be designed. The conceptual design phase is a dynamic and often chaotic process with a multitude of tasks to be supported. This demands greater freedom and more intuitive support tools. Experimentation is therefore more useful than a structural visualization approach. [1], [2]. These aspects did not receive sufficient attention in the development of the conventional design support means.
The target area of research and development of computer-based design support systems is gradually shifting from detailed design to conceptual design [1], [3]. In the last few years, freeform surface design tools have been introduced in CAD systems like SolidWorks 2007, but they are mainly useful to define global shapes and to modify surface features. When considering advanced design support for the early phases of the design process, there are two main problems to be taken into account: support for three-dimensional (3D) design and presentation of the design concepts, as well as support for intuitive and reflective modeling.

1.1 Support for three-dimensional design
Although most shapes to be designed are 3D, today's commercial computer-aided shape design software tools typically employ two-dimensional (2D) input, through devices such as mice and tablets [1], [4], [5]. As output devices, flat displays are used [6]. However, when working with 2D input and output devices it is difficult to understand and thus to design the proportions and dimensions as well as the ergonomic aspects of 3D products [7].

1.2 Support for intuitive modeling
In the early phases of design, efficient support of creativity, collaboration of designers and integration of information and knowledge are major issues [3], [4], [8], [9], [10]. Bodily input has proven to be

appropriate to enhance creativity and support social interactions during teamwork [2], [4], [11], [12]. In a creative process, speed of uttering and intuitiveness are closely related [2]. Utterance and visualization of creative thoughts should preferably happen as fast as the speed of creative thinking. Current design support tools however focus more on the issue of realistic modeling and rendering, than on an efficient support of expressing ideas [13].

These problems can be formulated as requirements for future digital design studios. Although it is difficult to forecast the future, these systems will probably incorporate both the currently available, and the emerging next generation design support tools and interaction technologies. They will include advanced sensing technologies for detecting, recognizing and processing speech, motion and gestures, and novel three-dimensional visualization devices, such as stereoscopic, volumetric or holographic displays. Extended with haptics, sound and thermal sensation, they will provide designers with more information compared to the conventional design support technologies. Our null hypothesis is that there will be a stronger and closer relationship between human, technology and application aspects in the case of these systems than there currently is with CAD systems. The goal of our background research has been to study the relationships between the human and application demands, and the affordances of the new technologies. This paper presents the results of an explorative study concerning the possible use and development of scenarios for the future digital design studios. First, we discuss the state of the art of advanced sensing and feedback technologies, which enable to support intuitive interactions with 3D modeling systems. Then, we discuss the designers' objectives towards the digital design studio of the future. The next session describes the usefulness of future scenarios in design, followed by three possible use scenarios of the digital design studio of the future. The paper finishes with an evaluation of the scenarios and the possible directions for further research that they imply.

2 INVESTIGATION OF EMERGING TECHNOLOGIES FROM HUMAN AND DESIGN APPLICATION ASPECTS

There are many technological developments which can support the early phases of a design process, like truly 3D visualization, intuitive interactions and haptic systems. However, a straightforward integration of all available technologies certainly will not result in the best possible digital design studio. It also depends heavily on the human and application demands, and characteristics. It is important to know what the designers need and in which way current and emerging technologies can contribute to fulfilling these needs. This section therefore discusses the main objectives of designers and the potentials of evolving human-computer interaction (HCI) technologies and advanced design support tools from the perspective of the digital design studio of the future.

2.1 Human aspects

In order to gain insight in the needs and wishes of companies and designers concerning the digital design studio of the future, 12 experienced designers from 5 different companies and 4 master students from 2 different design master courses were involved in creative sessions and interviews. The designers represented different industries, from industrial ship design to consumer products, and from multinationals to small design companies in order to form a representative sample group. The outcomes of these sessions and interviews formed the basis for a questionnaire about the requested support for idea generation, visualization and presentation, and the digital design studio in general. We randomly selected 25 designers who represented a broad spectrum of industrial designers, to participate in the questionnaire-based pre-structured interview. All participants had an engineering background, were working full time as designers, and were living in the Netherlands. We supposed that others designers with similar characteristics will have the same expectations as our sample group. Combining the input from the interviews and creative sessions, the questionnaire and the literature study, visualizes which aspects of the digital design studio are considered to be the most important. These are graphically presented in Figure 1. The numbers do not give a ranking of importance. Those aspects mentioned by different sources, represented by the overlapping areas, can be considered as more relevant.

Our analysis of the input from the companies and designers called our attention to the fact that they mentioned those aspects of design support that were important and at the same time problematic in their everyday work. A deeper look into the reactions pointed to the fact that designers have three basic objectives, namely to get support for (i) inspiration (to come up with ideas), (ii) visualization (to make the ideas tangible) and (iii) validation (to verify whether the ideas solve the problem at hand). The other aspects mentioned in figure 1 are means to support these three basic objectives.

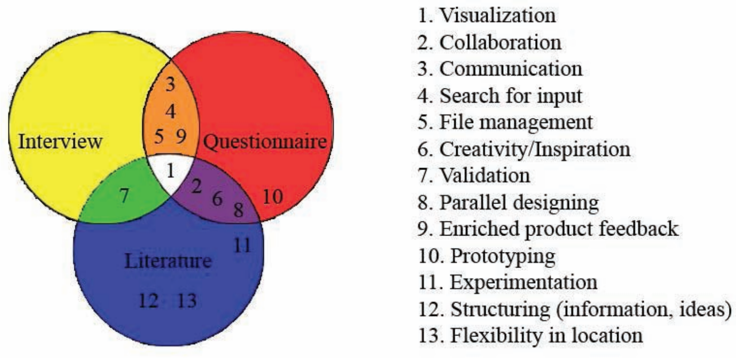

Figure 1. Requirements mentioned in interviews, questionnaire and literature

2.2 Emerging technologies

Advanced sensing technologies allow context awareness and implicit human computer interactions [14]. They are important to enable intuitive interactions by detecting, recognizing and processing speech, motions and gestures to support the creative processes of the conceptual design phase. Multi-touch systems, motion tracking devices, sign language recognition and speech recognition are useful examples of advanced sensing technologies. In addition, feedback can be used to increase the intuitiveness and precision of user actions by supporting the understanding of, and navigation within, digital models. Since designers deal with 3D physical products, the use of haptic and 3D visualization devices is an obvious requirement. Below, we elaborate on the most promising technologies and devices.

Multi-touch devices

Multi-touch devices are able to recognize multiple touch input simultaneously, in contrast to single-touch screens, which can only process one touch input at a time. The former devices are able to not only recognize multiple finger-interactions, but also to sense and recognize different objects (i.e. what the object is, where it is, and what its orientation is). There are two types of multi-touch interactions: multi-user interactions and single user multi-touch interactions. In the cooperation of designers, multi-touch can support synchronically interacting with a system; different users can interact with the system simultaneously. It is possible to use multi-touch on both sides of a screen, allowing users to simultaneously interact with the same spot of the interaction interface [15]. During single person multi-touch interactions, multi-point input can be used for a more intuitive HCI, e.g., to intuitively rotate, scale and manipulate digital objects. Although multi-touch is not a very recent development, it is not yet commonly used because most software is not compatible with multi-touch [16].

Motion tracking devices and sign language recognition

One of the most promising developments in the field of advanced design support is motion tracking. When using hand motion tracking as an input method, it can provide 3D surface information directly [5]. When motion tracking and information extraction happens in a specific domain of the 3D space, surfaces can immediately be generated at the required location. Hand motion-based shape conceptualization is possible by defining points in the air, which the system can interpolate or approximate to form a curve or surface [11]. Curves can also be created by tracking an object or finger tip, surfaces by creating closed curve pieces, or by tracking the entire hand movement [1], [2], [4], [17]. Sign language recognition is a method of interacting with a system using signs, which represent a command or instruction. A combination of hand motion tracking and sign language recognition, in which hand gestures form the signs to communicate with the system, can lend itself to intuitive ways of HCI [13]. Using sign-language recognition in collaboration among designers is an issue, which needs further exploration. Especially because person-independent recognition is much less accurate than person dependent sign language recognition [18]. This is explained by the interpersonal variance in signing caused by bodily differences and differences in muscular movements. Creativity will be hindered if the designers need to memorize too many signs. Besides hand motion tracking, head motion tracking or full body tracking can be interesting when designing the digital design studio of the future. Head motion tracking can be used to adapt the scenery on a screen according to the motions of the users' head. In this way, a three-dimensional experience can be created.

Speech recognition

Research showed that most designers prefer to use hand motion/gesture or voice command as input methods to create shapes, because they are natural means of expression [1]. However, it is difficult to describe free form shapes verbally. Speech engines, such as Dragon 4.0, are often used for speech recognition in HCI. Speech interfaces initially used small vocabularies of isolated words, like commands of computer systems, but can also be used for continuous speech recognition [12], [19]. Based on speech-only interfaces it is difficult to design morphologically intensive artifacts and to conduct complex tasks [19]. Voice recognizers must be trained to recognize the voice produced by a single person. It is still difficult to achieve fast and accurate speech recognition for the variety of different voices for different users [1]. Multimodal interfaces, like speech-gesture interfaces or speech-sketch interfaces, can help to overcome the problems of single model interfaces [11], [19].

Haptic devices

A haptic device enables its user to interact with a remote or virtual object through the sense of touch. Haptic devices often consist of an articulated mechanical structure with motors and position sensors, as well as embedded electronics. Typically, the user holds the haptic device in his hand, and moves it around both in the real world, and in the virtual world on the computer screen. Whenever his virtual hand makes contact with a digital object, a force value is sent to the motors, which simulate a real contact through force feedback. Haptic feedback can be used to increase the intuitiveness and precision of virtual modeling or modeling of digital visualizations on holographic screens, providing extra feedback and form information [2], [6].

3D display devices

3D displays provide the user with illusive 3D images or provide a real 3D visual. The following 3D displays deserve specific attention from the aspects of future digital design offices:

- Stereoscopic displays with user tracking. Currently these are the most common solutions to provide a 3D digital image [7]. Stereoscopic displays emit two distinguishable light beams from each pixel. The human eyes see a different image, and the brain combines those images into three-dimensional scenes. The generated image is only correct for one point of view and thus requires user tracking. Stereoscopic displays are also available as head mounted displays, or designers can use special glasses to provide the 3D image. To eliminate the need for user tracking or wearable gears, and to create a multi-view system, stereoscopic displays with ribbed surfaces are used. They are usually able to send the pixel light beams in different angles, and to produce 8-16 views per pixel. The introduction of more views per pixel however significantly decreases the resolution of the display [7]. Stereoscopic displays can visualize illusive 3D images, however these are not geometrically volumetric [6].
- Pseudo-volumetric displays generate images by projecting onto a rotating, semi-transparent, two dimensional image plane, or to a mirror with a holographic diffuser. Because of its physical enclosure, users are hindered to touch the virtual object, but it can be viewed from any direction [21], [22].
- Air-borne volumetric displays generate three dimensional images by reflection. For instance, laser beams reflect on small water droplets in 'mist-displays' (e.g. FogScreen), or on tiny solid particles (HoloDust), or laser beams can interfere with each other. Certain tasks can be performed more accurately and within shorter response times with a truly 3D (airborne and volumetric) display than by using a stereoscopic display [20]. On the other hand, they are still suffering from technological and usability issues.
- Electro-holographic displays generate holographic patterns to reconstruct the wave front [7]. With holographic displays, no viewing gears, like 3D glasses or head tracking devices, are

needed [6]. With proper eye-tracking and image control, several viewers can even simultaneously see the same 3D scene. Holographic displays are still limited in image sizes, viewing angle and suffer from computational limitations. An example of quasi-electro-holographic 3D displays is the HoloVizio. This system generates light beams in specially arranged optical modules to hit the points of a holographic screen with multiple beams in various angles [7]. In this way, the HoloVizio combines the technology behind stereoscopic displays with the advantages of holographic displays, resulting in better 3D performances than regular holographic displays.

When curves and surfaces are generated through hand motion tracking, it is preferable if visualizations of the surfaces and the hand motions happen in the same workspace; users can see the image of the generated surface directly under their palms [4]. Therefore, 3D displays like the HoloVizio are most effective, since the user is able to ‘touch’ the 3D visualization.

3 SCENARIOS IN DESIGN

Our study into the digital design studio of the future concerns several currently available and emerging advanced sensing and feedback technologies. Generating design proposals based on technologies under development could be problematic to accomplish, since their possibilities and limitations are not yet fully defined. To support creativity and the utterance of ideas, this study asks for an approach which supports envisioning the technologies and their possibilities as well as overcoming the conceptions of their limitations [23]. The future cannot be predicted or forecasted, but we can explore the range of possibilities. Examining the range and impact of uncertain factors for the future is the essence of scenario envisioning [24]. Scenarios can help users and developers to describe and evaluate the technology currently in use and envision activities that new technologies could enable [25]. Scenarios allow exploring the design space by making concrete design steps in varying directions, at times when the levels of knowledge gained do not yet allow for deciding on a definite direction [24].

In order to ensure the usefulness of design scenarios, we need to make sure that the concerned scenarios are; (i) relevant for the designers, (ii) sufficiently challenging for technology developers, and yet (iii) plausible solutions for the near future. To accomplish this, each of the proposed scenarios describes how support for inspiration, visualization and validation are taken into account. Below the technological concepts behind the scenarios are also briefly described, but not fully defined. All implemented and emerging technologies need to be known, but the latter do not need to be fully developed at the moment. This is important to emphasize because in order to be able to develop ground-breaking solutions we have to take into account the most probable trends and future technological developments . Finally, the proposed scenarios will envision the entire design process, following the same use-case; the design of a defibrillator/CPR system. In the use-case scenarios, we focus on how the major problems of current advanced design support tools can be solved by integrating advanced sensing and feedback technologies to support 3D feedback and quick and intuitive interactions.

We developed three different scenarios, all with a slightly different focus.

- *Scenario 1:* focuses on support for quick and intuitive visualization and validation by integrating different types of advanced sensing and feedback technologies. This scenario describes a more far-away future and includes relatively expensive technologies.
- *Scenario 2*: focuses on support for the design and visualization of product interactions and quick and easy validation of the usability of 3D products. This scenario uses relative inexpensive and currently available technologies.
- *Scenario 3:* focuses on support for inspiration and advanced visualization of the design concepts. This scenario is situated somewhere in-between the other two scenarios, both in predicted costs and expected time needed to develop the necessary technologies.

3.1 Scenario 1 - HoloVisio based digital design studio concept

The HoloVisio-centered design scenario concerns a digital studio with a Hawk Digital System with infrared cameras and retro-reflective markers attached to landmarks on the users’ hand for hand motion tracking and gesture recognition to generate 3D input. In combination with a speech recognition system, a 2D touch screen is used for context dependent input and a HoloVizio 3D display for real time 3D feedback and to allow the evaluation of form characteristics like proportions, dimensions and ergonomics. It is possible to combine this with a haptic system. The 'HoloVisio' scenario supports inspiration through facilitating a quick and intuitive visualization of ideas. The system allows 2D and 3D sketching and real 3D modeling and model manipulation using hand motion tracking, gesture recognition, speech recognition, and context dependent feedback. The designer is able to use experimentation, both for form and function, creating digital mechanical assemblies. Context dependent input is used to provide relevant inspirational information to the designer. Validation feedback during free modeling allows the user to design freely, but to also stay aware of the design requirements. The 'HoloVisio' scenario supports visualization by integrating intuitive visualization technologies with a real 3D visualization system. This combination of quick and intuitive visualization with truly 3D feedback to support the evaluation of proportions and dimensions limits the amount of time needed to visualize complex shapes. Simulation and analysis software, in combination with context dependent input, helps the designer to go through a complex multi-aspect assessment of the product concept, and to explain the possibilities and limitations to the client or stakeholders.

HoloVisio use-case scenario

The designer and client discuss the project at hand, using the 2D touch screen to look for information and reference material on the Internet (see figure 2a). The 3D display with hand motion tracking is used for 3D sketching to visualize what they are talking about. Hand motion tracking cameras follow the fingertips of the designer and client and gesture recognition is used to specify the preferred actions (draw, erase, move, rotate, etc.). The 3D display can also be used as multi-touch screen, allowing the users to make notes and quick 2D sketches, either using an infrared pen or on-screen fingertip interactions. Speech recognition can be used for common commands. The system uses context dependent visualization to support the designer. The 2D touch-screen displays programs commonly used within the recognized design phase. The designer can use online or local databases with components to design or test mechanical and electronic constructions. By selecting the components on the 2D touch-screen, they can be added to the assembly on the 3D display. If relations between parts and the necessary characteristics are added, an animation of the designed construction can be visualized on the 3D display. Surfaces, lines and common shapes are generated using motion tracking, gesture recognition and speech recognition, in this way allowing hand motion based 3D modeling.

Figure 2a. HoloVisio use-case scenario

The designer can resize, rotate and reform a model using hand motion tracking with gesture recognition (see figure 2b). The generated model can be manipulated in CAD programs and validation software can be used to perform load analysis. In this way, the designer can intuitively modify a model using hand motion based shape design and immediately evaluate the consequences. The designer can hide sections or surfaces in order to reveal hidden parts. An on-screen keyboard is used to interact with both screens. The designer presents his design proposal to the client. The 2D screen can be used to display additional information, while the 3D display can show the design proposal in real size. The client can rotate the model and easily point out areas of discussion or modify the design by hand. With validation software, the designer can explain the consequences of the changes made by the client. In this way, the designer can easily explain why some modifications are not possible or preferable.

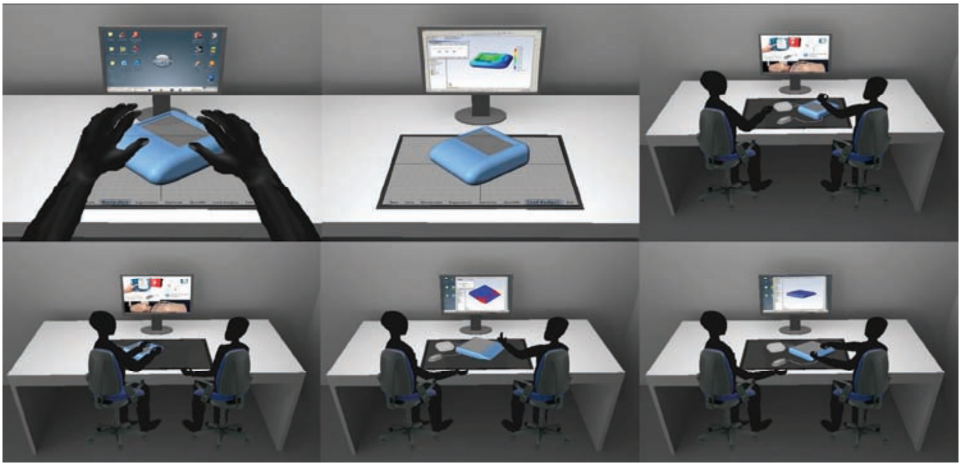

Figure 2b. HoloVisio use-case scenario

3.2 Scenario 2 - Projected Interactions based digital design studio concept

The 'Projected Interactions' scenario consists of a physical mock-up with embedded sensors, a motion tracking system in combination with a projector, and hand motion tracking for interaction with the projection. The 'Projected Interaction' scenario supports inspiration through experimentation. The designer can easily generate and evaluate interactive interfaces onto a physical model. This allows the designer to evaluate interfaces earlier in the design process and supports early user testing. By using physical models, the designer can evaluate form characteristics like dimensions, proportions and ergonomics both visually and through touch. The large projection surface provides the designer with a large sketch area to intuitively sketch different alternatives and to allow real size sketching. Although the 'Projected Interaction scenario' supports real 3D feedback, it does not support the 3D visualization process itself.

Projected Interactions use-case scenario

The designer and client discuss the project at hand, looking for information and reference material on the Internet (see figure 3a). A ceiling mounted camera projects the used interface on the table. The designer calibrates the area to project by selecting the four corners of the projection, or they can use a projection surface with light markers at the corners of the surface. If the projection surface is moved, the projected image is moved accordingly. They can make notes and sketches within the projection by hand, or using infrared pens. The designer uses the notes for inspiration and projects them next to him while using CAD software to visualize the design.

Figure 3a. Projected Interaction use-case scenario

The designer uses software like Visual Basic to design the product interactions (See figure 3b). He creates a physical model of the design proposal, from foam or by rapid prototyping. Markers (light sensors or reflective markers) are attached to the corners of the model. The designer presents the design proposal to the client, projecting the presentation on the table. The client evaluates the design, holding the model to evaluate the form and ergonomics. The projector with motion tracking system follows the markers on the model. In this way, the image is projected on the model as long as the model stays within its projection area. The projection adds both *visual information and functionality to the model, as hand motion tracking allows the client to interact with the projected interface. The designer can make small changes in the appearance and functionality of the design during the meeting, to immediately verify what the client wants. The client can interact with the model, try out and evaluate all the functionalities. The model can be used in combination with physical objects, in this case a First Aid dummy to test the design of a defibrillator/CPR system.*

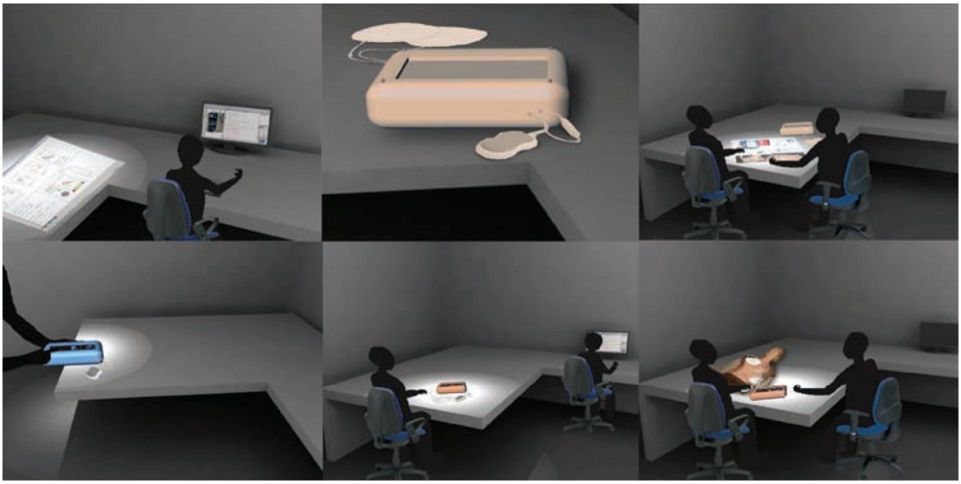

Figure 3b. Projected Interaction use-case scenario

3.3 Scenario 3 - Parabolic surrounding projection based digital design studio concept

The 'Parabolic Projection' scenario involves the use of a surrounding parabolic projection wall with surround sound, in combination with head motion tracking to create a 3D experience. By tracking two markers on the users head, the system can determine the location and orientation of the users head. This information is used to move the images on the surrounding projection wall in such a way that the user experiences the projection in 3D. Hand motion tracking is used to allow interaction with the projection. A large multi-touch table is included for real size sketching. The 'Parabolic Projection' scenario supports inspiration by surrounding the designer with sounds, images and/or movies related to the design context. Head motion tracking is used to simulate a 3D experience of both the product and its context. The designer is able to visualize the design within this design context, both in 3D and in real size. Potential users or systems, which need to interact with the design can be projected next to the design to evaluate whether the design fits the use-context. The designer can interact with the projected design to evaluate its functionality through hand motion tracking. The 'Parabolic Projection scenario' uses simulated 3D visualization, not real 3D visualization, making it less suitable for collaborative use.

Parabolic projection use-case scenario

The designer and client discuss the project at hand (see figure 4). They look for information and reference material on the Internet, using a large multi-touch screen. They use the screen to make notes and sketches. The designer projects images or movies of the context of use of the product concept on the parabolic wall for inspiration. In this way, the designer is surrounded by the design context. The designer uses the large multi-touch screen for sketching. The designer creates detailed visuals using visualization software on the large multi-touch screen. He uses CAD software to model all parts of the design, while the detailed design sketch is displayed on the table. The designer presents the design proposal to the client, displaying the presentation on the table and the context on the wall. Another option is to display the presentation in the context on the wall, allowing the client to make notes using a notepad on the multi-touch screen. The client evaluates the design by viewing and interacting with the virtual model on the projection wall. Head motion tracking is used to move the projected image according to his head, using an infrared camera with infrared array and infrared reflectors on the users' head. The client experiences the product and projected environment in 3D. The client can move the model or parts of the model using hand motion tracking. By projecting the design proposal in its context of use, the client can evaluate the design by using it. Parts of the design can be dragged towards the right position and the projected product interface can be used. The client can sketch directly on the displayed model to suggest changes or to point out areas of discussion. To immediately verify what the client wants, the designer can make *small changes in the interaction software and CAD models to modify the appearance and functionality during the meeting.*

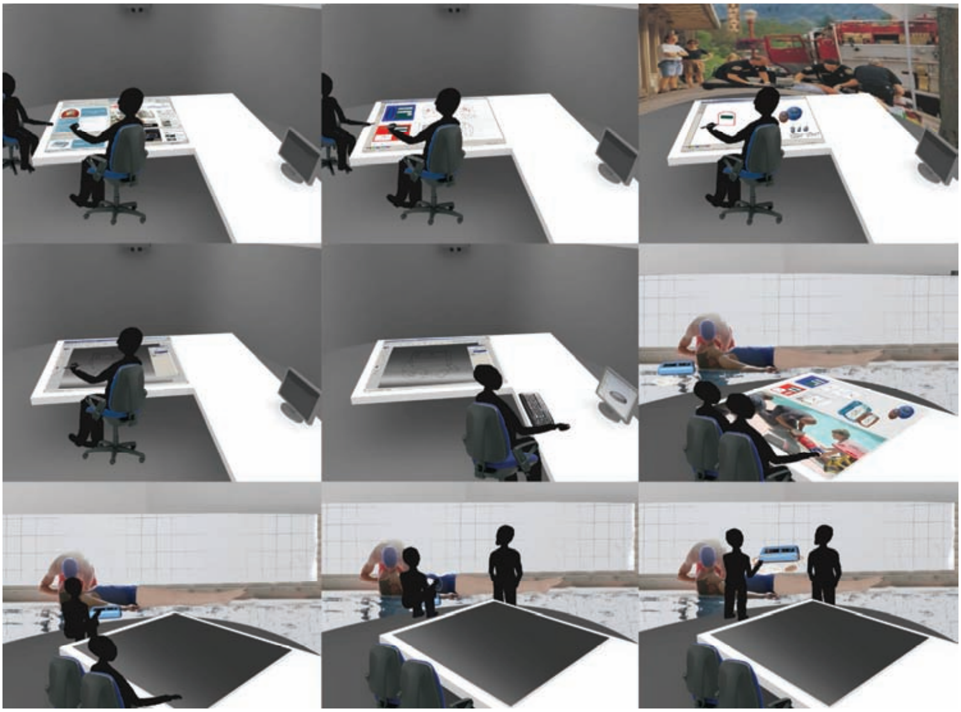

Figure 4. Parabolic Projection use-case scenario

4 EVALUATION OF THE SCENARIOS

In this paper, we presented three different use-case scenarios of future digital design studios. Firstly, to evaluate the quality of the scenarios, we evaluate how well they fit with the requirements. Do they support the main objectives of the designers through the entire design process? Do they support three-dimensional design and intuitive modeling? Secondly, in order to evaluate the usefulness of the presented scenarios, it is important to evaluate whether the scenarios fit with the expectations and wishes of future users. Our purpose was to qualitatively analyze the responses of the test persons, in order to be able to explore the meanings, intentions and visions, rather then to provide statistical evidences.

4.1 Inspiration, visualization, validation

Since the scenario design is based on support for the main designers' objectives, all three scenarios support inspiration, visualization and validation throughout the entire design process. The 'Projected Interaction' scenario and 'Parabolic Projection' scenario do not truly support intuitive three-dimensional modeling. They therefore are less suitable as digital design studios of the future compared to the 'HoloVisio' scenario. The 'Projected Interaction' scenario is to be seen as an interesting and useful design tool but not as an entire design studio. The 'Parabolic Projection' scenario can be considered as a design environment. Current design studios are desktop-based. In the near future, current design studios can be integrated into this environment. In this way, designers are surrounded with a rich feedback environment, context awareness is increased and creativity can be supported. Such an environment is very suitable to support both face-to-face and remote collaboration among designers. For the digital design studio of the future, more advanced design support tools, as presented in the 'HoloVisio' scenario can be integrated in the 'Parabolic Projection' environment.

4.2 Confirmative testing with potential users

A subset of the interviewed designers, those who had the strongest vision, were asked to evaluate the proposed scenarios. Firstly, the various movies of the scenarios have been presented. The 'HoloVisio' scenario is especially appreciated for its ability of supporting truly 3D intuitive modeling. The 'Projected Interaction' scenario is considered to be useful because of the support to design and test truly 3D interactive products, which is not yet possible in current design studios. The 'Parabolic Projection' scenario is evaluated as an inspirational environment with many possibilities to support intuitive processes in the early phases of the design process and during presentations. The large interaction surface in combination with a 3D working environment is considered to be useful for tasks like brainstorming, sketching and evaluation of designs. It is intriguing to see that people evaluated the scenarios as an interesting package of advanced design support. Instead of adopting one of the scenarios, people wanted to combine the three scenarios. The parabolic projection wall, in combination with the intuitive 2D and 3D design support of the 'HoloVisio' concept, has been considered to be an inspiring and intuitive form of a digital design studio. Several people wished for the principle of the 'Projected Interaction' scenario to be integrated in the 'HoloVisio scenario'. This could be accomplished by using haptics with 3D digital visuals instead of physical mock-ups. Presentations of the scenarios also stimulated designers to think further, to come up with other ways to support intuitive 3D modeling in the future. Overall, the scenarios were evaluated as inspirational and provided stimulation to further develop the concept of the digital design studio of the future. The chosen directions are considered to be promising. Designers are looking forward to working with technologies like the ones presented. One of the companies involved wants to continue in this direction and asked for a project to further the study of the possibilities of the 'HoloVisio' scenario within their company.

In order to study and to communicate the possibilities of the technologies behind the scenarios we developed a proof of the concept of the 'HoloVisio' scenario and of the 'Parabolic Projection' scenario. In the 'HoloVisio' proof of the concept, a HoloVizio 3D display is combined with a Hawk Digital System for hand motion tracking with infrared cameras. With the use of hand motion tracking and gesture recognition, users are able to perform simple 3D sketching and 3D surface generation tasks. The same system is used to allow 2D multi-touch interactions like dragging and rescaling images for collage making. One group of participants was asked to interact with the presented proof of the concept. Another group of participants watched a movie of the proof of the concept. Both groups were positive about the potentials of the system. Those who had been able to use the system however, mainly elaborated on the possible problems instead of new possibilities. By showing a movie of the proof of the concept instead of letting them to be faced with all the accompanying challenges, the participants were triggered to think ahead. In this early stage, it can therefore be more useful to only show movies or simpler, but good working prototypes in combination with future scenarios.

In order to explain the principle of creating a 3D experience through head motion tracking, as used in the 'Parabolic Projection' scenario, we built a small scale proof of the concept using a simple infrared camera, a laptop and glasses with two infrared LED's. With this proof of the concept, users are able to experience the 3D effect, but not manipulate or generate an image. Although this set-up is very limited in functionality, is does stimulate participants to elaborate on the possibilities instead of the downsides.

Our research did not cover a complete testing of the proposed systems. The scenarios were used for opinion forming. The proofs of concepts were employed to communicate the possibilities of the technologies behind the scenarios.

5 DISCUSSION AND CONCLUSION

At a time when the levels of knowledge gained so far does net yet allow us to decide on a definite direction, we conducted research to gain more insight in possibilities to develop future digital design studios, incorporating traditional and emerging advanced technologies. Our assumption was that the development of future digital design studios can be supported by use case scenarios through making the relationships between users and the system (environment) explicit, contextualized and tangible. We also assumed that evaluating these scenarios makes envisioning and testing alternative workflows and resource arrangements possible. Our experience showed that scenario-based envisioning is a good method to explore and communicate the range of probable design directions, and to visualize complex ideas and novel technology embedding in an understandable way. With scenario envisioning, people are more triggered to think about the possibilities rather than about the difficulties of design proposals.

In this paper, we presented three concepts of future digital design studios on the basis of three foreseen scenarios. Our research explored that the main expectations in terms of supporting designers were: (i) inspiration, (ii) visualization, and (iii) validation. The fact that both the interviewed companies and the individual designers showed great interest in the presented scenarios indicates that there is a need for more intuitive modeling tools and three-dimensional feedback in product conceptualization. Moreover, in line with our null hypothesis, a closer relationship between human, technology and application aspects are to be developed. Though technology plays an important role, it should become invisible and adaptive, and omnipresent in the near future. Although inspiration, visualization and validation aspects should be supported by the set up of the future digital design studios equally well, the current and the known emerging technologies are yet not capable to support this.

Intense further research is needed in this important field, considering all the potential trade-offs. For the near future we propose the following issues for research:

- Exploring efficient solutions for supporting quick and intuitive spatial concept modeling and manipulative interaction, as well as detailed shape design. Also to define other product characteristics, using hand motion tracking and recognition, and real time interaction simulation;
- Working out platforms for the integration of component technologies and support solutions into the infrastructure of future digital design studios;
- Moving towards multi-sensational (e.g. haptics in combination with truly 3D visualization) interaction with product concepts and making this an opportunity for the stakeholders of product conceptualization;
- Further investigation into the possible extensions of the future digital design studios with ad-hoc connected, mobile and ubiquitous design support tools;
- Investigating the cognitive aspects of working with advanced multi-model interfaces.

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