Title
Human-Object-Interaction in Engineering and Art / Scenes of Kinetic Sculptural Objects

Authors
Prof. Franziska Hübler
University of Applied Sciences Hamburg, University of Applied Sciences Hamburg, Department Design, Art Installations

Prof. Dr. Birgit Wendholt
University of Applied Sciences Hamburg, Faculty of Engineering and Computer Science, Department of Computer Science

Prof. Dr. Gunter Klemke
University of Applied Sciences Hamburg, Faculty of Engineering and Computer Science, Department of Computer Science

Abstract
Our collaborative research is about joining the fields of natural user interfaces, mixed reality, three-dimensional environments and user-interaction from a computer science and art & design perspective. Employing technologies and methods in these fields, we are investigating the design of interfaces between the virtual and real world in order to create intuitive interactive forms. To achieve this we set up experimental environments that we call “scenes of kinetic sculptural objects” where we evaluate the acceptance of proposed interaction patterns between humans and objects. Creating environments involves incorporating virtual objects into physical scenarios; designed and developed at the intersection of physical and virtual space, while modeling the behaviour of the environment and the immersion of the viewer. The spaces we create are made tangible through the users’ senses, i.e. employing 3D printed and handcrafted objects. For natural intuitive interaction we are engaged in the development, detection and evaluation of 3D gestures like dynamic hand and body poses. In terms of mixed reality we annotate real objects with 3D projection mapping onto moving and changing objects.

Introduction
Interdisciplinary research requires a definition of the subject area that “opens the door” for a creative contribution of both sides. Our working title “scenes of kinetic sculptural objects” was invented to exactly serve these means. With “scenes” we denote storyboards for interactive environments of objects and humans. With “kinetic sculptural objects” we address the questions of coping with 3D environments. These objects are used as substitutes for objects in the physical
world.

Interacting with the objects allows us to examine recent kinds of natural user interfaces. Annotating them with digital content enables us to experiment with mixed realities. From a technical point of view our working title sounds a bit esoteric but it has proven as a strong metaphor that leads to current research problems even in the computer science area. From an art perspective we are interested in shaping the environments - finding the right form and material. When working with projection and video mapping we are exploring materials that create spatial illusions.

We are also inventing a meaningful metaphor that can be associated with the installations using contemporary technology. Our approach is part of our methodology which will be further elaborated in the next section. In what follows, we briefly sketched related work of similar scope and intent.

The major part of this paper introduces the results of our cooperative work. We will show the development of our joint research by introducing short term projects as experimental playgrounds for technology and methods. Proceeding to the long term projects we will discuss the more demanding research questions. The conclusion gives a concise summary and outlines the research issues we are currently working on.

**Methodology**

As a starting point for our projects we use sketches; both digital and physical materials have a lot of hidden potential that we often discover within the playful and sometimes even unintended "sketch". To create a running spatial installation we move from a sketch to a working prototype. These aren’t just prototypes, but a way to test the feasibility of an idea including the first steps in shaping the user experience. Depending on the feedback of the user and overall functionality, the project is continually iterated upon until a solution is found.

Our role as educators is to provide the students with a general outline of a conceptual idea including technical prototypes that we let the students modify. Within this framework the students are able to develop their own ideas which we advise them from technical and artistic point-of-view.

The students projects are created in mixed groups consisting of designers and computer scientists. Both disciplines are involved in the process of creating the concept and the implementation of the projects. Each discipline develops an empathy and understanding of the opposite discipline, which enhances quality of the projects.
The majority of our projects consist of short term projects which are made with students with no or very little prior experience in creating interactive installations. A handful of students have worked with us over several years through their BA and Master.

In long term projects we address more challenging problems relevant to research in both areas. Working in this very complex field of mixed reality environments, the quality of projects get a lot better because of iterative refinement over time.

Related Work

The following are examples of installations and solutions that are closely related to our own work and research. The relevance for our work is argued in each paragraph.

Jeffrey Shaw's „Emergences of Continuous Forms“ (Duguet 1997), was created in 1966. This was one early artwork dealing with the idea of extending the cinematic experience into the physical space and provoking the viewers participation within the artwork. The relevance for our research is that he merges the virtual space with the real spatial objects. He also includes the visitors as participants. For „Emergences of Continuous Forms“ he hung semi-transparent projection screens in two rows across the gallery space, which created the effect of materialization of the film in the space. There were tubes connected to the screen. The tubes let people inflate balloon, this changed the shape of the screen. Smoke was let from one screen to the other. Jeffrey Shaw has created lots of well known installations that are using digital media and physical objects.

The collaborational sculpture "Textile Room" (Reas 2012) was created by Casey Reas and the architecture studio P-A-T-T-E-R-N-S and North Sails' Flexible Composites division. The sculpture deals with the growth and transformation of the city Los Angeles. It consists of an architectural sculpture, that merges the opposites hard and soft, transparent and translucent, of intimate and public. The semitransparent surface is projected with generative video-clips of movies of Los Angeles. The activation of the sculptural happens through the Los Angeles Urban infrastructure. Though the installation is missing interaction with the visitor, the relevance of this work is an impressive transformation of scenes in the real world into animated objects.

White Kanga (White Kanga 2012), a polish multimedia company, has developed a 3D projection system for moving objects, the interactive Kinetic Modeling System (iKMS Trade Arabia News Service 2013), whose potential has been presented in multiple installations. The idea behind the solution is to synchronize projected images with the rotation of a motor engine with respect to the viewer. In (Kirn 2012) the installation object consists of a 50 kg vinyl polymer structure (approximate height 3.5 m) which is connected to motors and controlled via an Arduino. Three projectors are controlled by means of a powerful graphics card. The relevance for our work is
that the team merged moving 3D objects with 3D projections and created impressive mixed reality worlds. In contrast to our work, the team uses physical knowledge for the mapping task, whereas we need real time vision based 3D reconstruction methods, since objects in our installation can move and deform deliberately.

**Ongoing Work**

Our collaborative interdisciplinary team of designers and computer scientists has over three years of experience researching in the field of interactive mixed environments. A number of projects have been developed in joint work, while all of them have been exhibited in a public space. We will outline a selection of projects in order to expose our development stages. The projects are grouped into short term and long term. Short term projects are semester work of our students. Long term projects take between 1 and 2 years and are cooperations between students of both disciplines working on their bachelor or master thesis.

**Short Term projects**

**Project Reactive Landscapes (2011)**

This project utilizes a web a camera as sensor as well as several prototypes for motion detection and the mapping of visual input onto objects. The creative aspect was to correlate visitor’s motion with reactive objects:

![Image](1)

**LED-Land**

The mixed reality landscape (1) looks like an abstract mountain, river and sky. It was built out of foam elastic-fabric and LED-stripes that are controlled by an microcontroller (Arduino). The
river pulses to mimic the movement of real water. Visitors interacting with the landscape change the projection of the animated sky and the color atmosphere of the LED's of the mountain.

WAVE
The mechanic movement of "the wooden wave" (2) was inspired by puppets. The wave followed the movement of visitors. Therefore, the camera stream was mapped onto vertical segments that relate to the segments of the wave. Movement in one image segment controls the movement of a corresponding servo that mimic a wave.

Lessons learned: All installations provided an extremely intuitive interaction; visitors understood the dependencies between acting in the real world and the virtual effect incorporated in the objects. Hence, the interaction was of a very simple kind and didn’t allow for targeted or individual and cooperative interaction.

Project Action Painting (2011)
The announcement of the Kinect sensor and the provision of OpenNI has simplified the development of visual based interactions. Analysing 3D scenes and body structure, recognizing gestures as well as user tracking are functionalities available today. In this project we exploited these features to create virtual worlds that mimic real scenes.
Inksphere
In this installation the group created an interactive space for cooperative gesture based painting. The work was inspired by Robert Motherwell and the “rotating canvas” of Alfons Schilling. Creating an painting canvas as projected sphere, the students transferred the 2D canvas into a virtual 3D space. Depending on distance and velocity visitors are drawing lines of different width in the virtual sphere. The movement of the visitors on the playground is mapped onto the rotation of the virtual sphere. Balancing the sphere depending on the position of different visitors allows for cooperative painting.

Cy M Y K
The Cy MYK installation is an interactive painting environment. The installation combines the idea of action painting with the dynamic movement of wind. The setup of the installation consists of a fan, a Kinect camera and the projection of the paintings, that the visitor can create through their physical gestures. The painting moves through the mixed media space with the wind, that is physical and virtual factor in the environment.

Lessons learned: The interaction in both installations was designed so that visitors easily understood the effects of their behaviour with animations that are plain and clear. Our next research question was, whether more ambitious animations will increase the immersiveness of the virtual scenes.

Project Spieglein Spieglein (2012)
The main goals of this project were (1) to find abstractions for mirrors in projecting art work and (2) to animate complex physical phenomena in order to further bridge the gap between the virtual and physical world. Two of the five teams met these requirements very well:
Dynamic District
The interactive spatial installation "Dynamic District" consists of physical geometric sculptural elements and a virtual projected fluid space that is constantly changing with a 3D-camera detects visitors in the space. The moving particles are flowing around the silhouette of the people and the geometric shapes of the sculptural elements. The virtual and physical are merging into a mixed reality.

Identity
We are a reflection of our surroundings; unconsciously we mimic the behavior of the people we are in contact with. People are changing through us and we are changing others. The idea for "Identity" was to create the picture that contains particles of the previous picture of the visitors of the installation. When the visitor comes to the installation they find a stack of particles that consists of the previous visitors. The picture of the visitor is created out of hundred thousand particles that fall apart and get put together again. Because of the huge number of particles the simulation is calculated on the GPU with OpenCL.

Lessons learned: The most interesting observation is the intermingling of virtual and physical aspects in mixed reality scenes, such as in “Dynamic District”. There have been several inquiries to show the installation.

Project Reactive Fragmente (2012)
In this project we decided to further elaborate the potential of mixed realities. We lead the initial direction of the students into the area of projection mapping and let them experiment with a couple of non-visual sensors. The following two projects show two different interpretations of this scope. As a source for inspiration we have chosen the book of Italo Calvino Invisible Cities.
Ottavia
The interactive sculpture Ottavia (4) is built out of paper pyramids that form the net of the city. This sculpture was designed with a very fragile interaction that referred to the uncertainty of the city. The paper corners of the object are traced by the projection via projection mapping. The visitor of the installation are captured by a 3D camera. Through hand gestures the visitors can physically interact with a virtual net and pull it like a rubber band. The movement of virtual rubber band is calculated through the software.

Despina
The sculpture translates the story of Despina into an abstract form and behavior. The form is based on the idea that the city sounds echo the shape of the waves. It contains of a wooden box that has 32 Servos built in raster that pulls the elastic fabric. The sound waves undergo a fast fourier transformation whose outcome, the loudness of notes, is mapped onto a servo motion.

Lessons learned: The visitors intuitively understood the environments. Thus our next short term project starts over to further develop interaction between objects and visitors. For the current course we have addressed the following topics: (1) projection mapping onto Kinetic objects and (2) further improvement of interaction patterns.
**Long Term Projects**

Long term projects are the further exploration of a variation of a short term projects with the goal being: to experiment with technology and methods while yielding a set number of intriguing research questions. We arrange teams of two students (one of each discipline) that work on relevant issues. Moreover, short term projects have shown the need to invest in infrastructure projects in order to facilitate our ongoing cooperation. We will give one example for each of these aspects:

**Mixed Realities**

Iwer Petersen und Janina Schlichte (a multidisciplinary team for over a year) are working on projection mapping onto kinetic objects. They started projection mapping with experiments on 2D interactive objects. Their collaboration has created over 10 installations that have been exhibited in several European museums and galleries.

Since 2D projection mapping and 3D mapping onto static objects is well understood in the computer science field, in his bachelor thesis Iwer dealt with 3D projection mapping onto moving objects. Starting with a model based object separation and registration, he solved the problem with an 3D online tracking procedure. The results of his bachelor thesis contribute to the fields of 3D reconstruction (ACM Multimedia 2013)(5) and texture mapping onto 3D objects. In the course of his master studies he is further developing his topic towards real time 3D reconstruction and mapping.
Janina’s background lies in textile design. She has been working on interactive sculptural surfaces and environments for 5 years. Janina is researching on sculpting 3-dimensional-surfaces that deal with spatial illusions. Her work is referring to kinetic art, abstract experimental movies as well as abstract sculpture. Her surfaces and environments are created out of reflective materials like fabric and paper that she combines with LEDs and projection-mapping. For her bachelor thesis (Schlichte 2012) (6) Janina created the interactive environment Plus-Minus-Space in cooperation with the computer scientist Simon Alt.

Infrastructure
Every time we construct interactive environments our students start with an Arduino toolkit. The next project is about providing a starter kit for communicating objects. The interior of the objects are provided as modular boxes with pluggable sensors and actors, communication capabilities and configurable behavior that allow for dynamic assemblies. Arduinos and a Raspberry Pi define the platform. The students René Schulz and Annette Schmid are working out the infrastructure and it’s potentialities for immersive art installations.

Conclusion and Future Work
In this paper we gave a brief overview of our cooperation. As we stated in the introduction, our overall goal is to bring together the fields of natural user interfaces, mixed reality and three-dimensional environments from two perspectives. In our short term projects we succeeded to apply “off the shelf” technology within the curriculum. The long term projects are more challenging because the results contribute to current research in both disciplines. Our observation is that interdisciplinary work in the above mentioned fields leads to relevant questions for both
disciplines and creates a highly motivating hands-on environment for students to cope with that challenge theoretical issues.

There are a few of open questions and tasks for future work. For the computer science these include: (1) 3D online reconstruction and texture mapping, (2) 3D gesture recognition, (3) 3D overlay and annotation of natural environments, (4) toolkits for gesture recording and recognition, (5) usability of natural user interfaces and (6) interaction with virtual likeness. All of these subjects are currently elaborated within the scope of bachelor and master thesis. From an art point of view these are: (1) creating complex kinetic environments (2) sculptures and objects that mimics complex behavior and (3) researching on physical materials that are feasible within the context of projection.

References


