DRIFT – Virtual Sand in augmented Space

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Abstract

Drift is an interactive audiovisual installation that overlays the appearance and behaviour of a generative mechanism with the properties of a surrounding physical space. This installation forms part of a series of works in which the authors experiment with generative approaches to augmented reality. These works place a particular focus on merging simulation-based and natural systems not only of the level their respective appearance but also with respect to their underlying physical and behavioural properties.

In this installation, the generative system is based on simulated sand grains that move across a virtual relief. The relief is derived from a combination of the physical properties of the exhibition space and a geometrical representation of an imaginary space. The installation itself consists of a rotating platform that houses a camera, a video projector and two directional loudspeakers. As the platform turns, the camera and projection scan across the surrounding space. The virtual relief to which the simulated sand grains respond to changes in accordance to the scanned space. At the same time, the behaviour and distribution of sand grains becomes perceivable as an acoustic and visual projection that is aligned and superimposed with the physical appearance of the scanned space. Visitors who are present in the exhibition space automatically become part of the generative processes. Their presence alters the space perceived by the scanning mechanism and their appearance also becomes subject to the process of audiovisual superposition.

1. Introduction

Drift is a generative artwork that creates synthetic audio and video based on an analysis of its surrounding space and employs this output to alter the appearance of the space. Its consists of a motorized rotating platform that carries a distance sensing camera, a video projector and two ultrasonic loudspeakers. As the platform moves, the camera traces the surface of the space. The trace serves as a common ground for two otherwise independent processes: the generation of a visual and acoustic output. These two outputs are projected on the same surface region that has been traced by the camera. As a result, the characteristics of the physical space gives rise to dynamic and intangible processes that transform the formerly static appearance of the space into a fluid and malleable environment.

The realisation of this artwork is motivated by the authors long standing interest to employ generative systems to extend and augment physical objects and environments (see for example [Bisig and Tatsuo 2010][Bisig and Palacio 2014]). The artistic format of an installation offers the opportunity to develop generative processes that mirror in a literal or metaphorical sense the close relationship between the structural and perceptual characteristics of a natural space. The challenge and prospect of this approach consists in the design of a generative system that maintains an intimate relationship between space, light and sound but at the same time renders this relationship amenable to creative experimentation beyond the natural constraints of a physical space.

The approach of extending and transforming an existing physical space by artistic means constitutes an interest that is shared by several artists. This interest is often motivated by a desire to transcend the physicality, solidity and permanence of a space. In many of the resulting installation artworks, light plays a particularly important role as a medium for the transformation of space. The following section provides a cursory overview of some of the works that have been realised in this context. A particularly rich artistic outcome has emerged from the californian art movement “Light and Space” [Clark and Auping 2011]. Pioneering members of this movement such as James Turrell or Doug Wheeler employ light in order to transform the perception of a space and to provoke a liminal experience [Adcock and Turrell 1990, Kennedyian 2012]. Among their works feature installation series such as the neon light spaces by James Turrell and the light walls by Doug Wheeler. A similarly classical series of installations named “Lichtballett” have been realised in Germany by the artist Otto Piene [Gerson and Daffner 2002]. These light-based installation are realised as kinetic sculptures that create shifting light patterns across surrounding walls of the exhibition space. Among younger generations, artists such as Barbara Kasten [Qiu 2015] or the London bases art collective “United Visual Artists” continue this tradition of manipulating space via the medium of light. For instance in her piece “Axis”, Barbara Kasten employs shadow, color and lighting effects as a means to render a space ambiguous and fluid. The work “Momentum” by the United Visual Artists [United Visual Artists 2014] turns the space of the Barbican Centre’s Curve gallery into a spatial instrument, that consists of a sequence of pendulum-like elements. These swinging pendulums emit sound and light which they project across the 6 metre-high walls and curved floor of the space.

2. Concept

This work has been realised as the most recent incarnation of two general concepts that inform many of the authors collaborative artworks so far. The first general concept has already been mentioned and refers to the augmentation of natural objects via the application of algorithmic principles. In a simulation-based approach, the algorithms are designed to model some of the structural and behavioural aspects on which the appearance of these objects is based. The creative experimentation which these algorithms leads to a perceivable output that preserves some of characteristics of a natural object's appearance.

The second general concept is related to the fact that the creative experimentation with algorithmic principles has important implications for works that incorporate multiple media. If each of the individual media is created through the activity of a common set of algorithmic rules, then these rules imprint across these media a formal relatedness that becomes perceivable as a consistency of appearances. This consistency is inherent to the creation process of each of medium and therefore doesn't require any form of coordination among the media in their creative design.

In the specific case of Drift, the object to be augmented is the exhibition space. The incorporation of the physical and perceptual characteristics of this space is the core principle of this artwork. The simplified representation of the space as three dimensional surface reliefs forms the basis for the formal relationships between the physical aspects of the space and its visual and acoustic properties. The analysis of these surfaces serves as basis for the operation of the generative algorithms and the rendering of the installation's visual and acoustic output. Just as these surfaces serve as live input for the generative algorithms they become subject to manipulation by the installation's synthetic audio and imagery.

The augmentation process is geared towards a manipulation and superseding of the predominately static and solid characteristics of physical space. By creating and projecting a synthetic audiovisual output from generative processes that respond to the surface characteristics of the surrounding space in a very dynamic way, the permanence and tangibility of the space's original appearance is partially superseded by the fluidity and intangibility of computer generated audiovisual material. Furthermore, the spatial surfaces that act as input for the generative processes, don't necessarily have to be present in the real physical space, but can be generated synthetically by additional computational processes. These synthetic surfaces can represent virtual spaces whose properties can significantly deviate from a physical space. By combining the inputs from a physical space and one or several imaginary spaces, the response of the generative processes and the resulting audiovisual projection originates from the presence of a hybrid space. It is this combination of dynamic generative processes and virtual spaces that imbue the physical space with aspects of intangibility and dissociation from local reality. The extent of this augmentation and its ephemerality is emphasised by the fact that the installation kinetic activity. As the installation rotates, the surface regions (both physical and virtual) that serve as input for the generative algorithm continuously changes. As a result, the augmentation manifests via a narrow but dynamic audiovisual projection that briefly supersedes the local characteristics of a region of physical space after which this region return to its former natural appearance.

Due to the fact that the installation operates with life input in order to analyse and modify the surrounding space, the augmentation process is part of a mutually dependent feedback loop between physical space, generative processes and audiovisual superposition. The existence of this feedback loop becomes apparent in the installation's site specificity and the interaction possibilities of visitors. The real-time characteristics of the installation allow the generative processes to respond differently to the varied surface configuration of different spaces. As a result, each exhibition setup provides a unique situation within which the augmentation feedback loop unfolds. With respect to interactivity, visitors of the installation become automatically part of the augmentation feedback loop: their body surfaces serve as input for the generative algorithms and in turn becomes subject to a superposition with the installation's synthetic audio and video.

3. Implementation

3.1 Hardware

The hardware setup and the cabling among the different devices is shown in Figure 1. The housing of the installation is divided into two compartments. A closed stationary lower compartment contains a hall effect sensor, a DC Gearmotor with integrated rotary encoder, a motor driver, a motor controller and a microcontroller. An open upper compartment which is able to rotate around a central axis carries a video projector, two hyper-directional loudspeakers each with its own audio amplifier, a distance sensing camera and two computers. A small magnet is attached underneath the bottom platform of the upper compartment. This magnet is sensed by the hall effect sensor and thereby indicates a reliable reference orientation. The upper compartment is supported by four ball bearing wheels that are attached to the top plane of the lower compartment. The motor transmits its torque via a belt to the axis of the upper compartment. The axis contains a three pole sliding contact through which electrical power from the lower to the upper compartment is transmitted. Control and sensing data concerning the motor's position and speed is sent wirelessly via a point to point connection between two Xbee modules. Among the equipment placed on the rotating platform, the loudspeakers deserve a more thorough description. Each of them consists of a disk-like arrangement of multiple ultrasound emitting capsules which together emit a highly directional audio beam. This inaudible ultrasonic beam acts as carrier wave for a sound signal which becomes audible only when the beam hits an obstacle. In this situation, the obstacle becomes perceivable as source from which the sound signal originates.

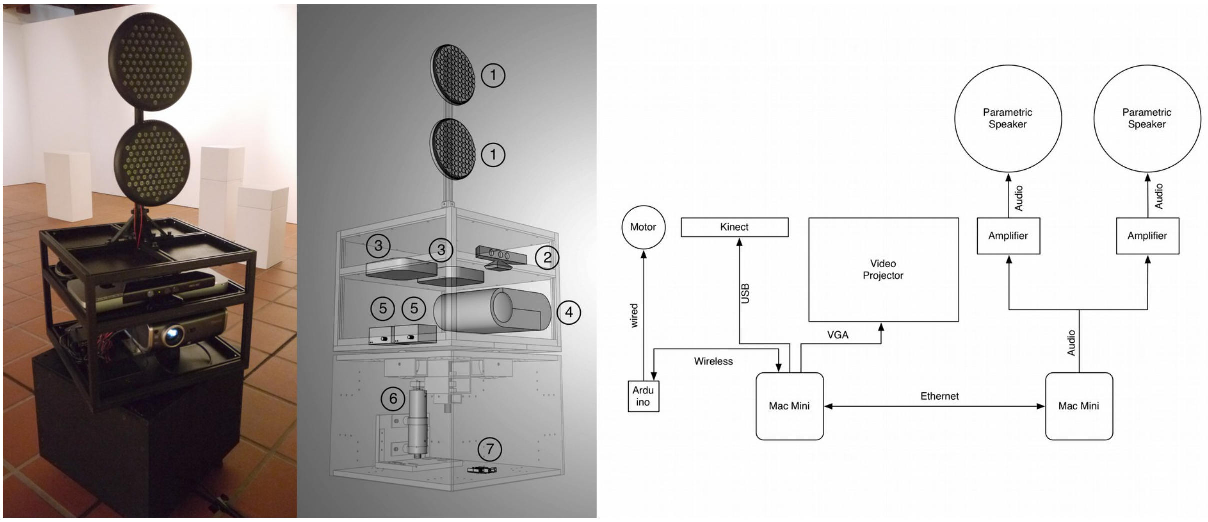

Figure 1. Installation hardware. From left to right: a photograph of the installation within the exhibition space, a schematic depiction of the installation hardware, a schematic depiction of the individual devices and their cabling. The numbering in the middle image refers to the following devices: 1) parametric loudspeakers, 2) distance sensing camera 3) computers 4) video projector 5) audio amplifiers 6) motor 7) micro controllers. For the sake of simplicity, the motor driver, motor controller, hall effect sensor, magnet, and sliding contact are not shown in this image.

3.2 Software

An overview of the software components that control the installation as well as their communication protocols is given in Figure 2. The microcontroller runs a motor control and communication software. The first computer runs a motor control and communication software, the main installation application that comprises functionality for video tracking, simulation and visual rendering, and a watchdog program for job monitoring and program scheduling. The second computer runs the sound synthesis software and another watchdog program. These individual software components are described in more detail throughout the remainder of this section.

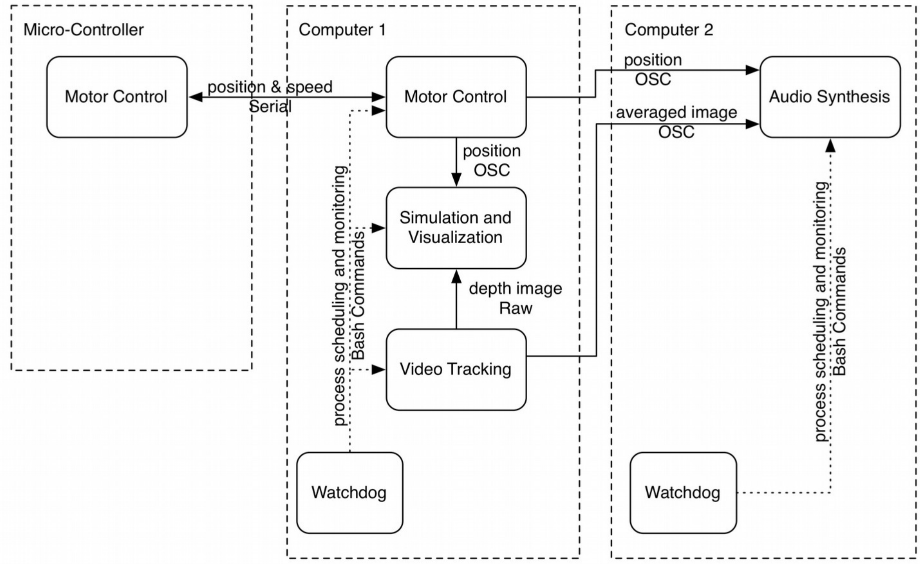

Figure 2. Software and protocols. The image depicts the software components that run on the micro-controller and the two computers as rounded rectangles. Most of these components represent individual applications with the exception of the "simulation and visualization" and "video tracking" component which are part of the same software. Solid lines indicate communication channels among software components. Dashed lines indicate the scheduling and monitoring activity of the watchdog software. The line labels describe the type of data that is being exchanged and the protocol used.

3.2.1 Motor Control and Communication (Microcontroller)

This software directly controls the position and speed of the motor. The software communicates with the first computer by receiving control settings for the motor's target position and speed and by sending the motor's current position and speed. This software also maintains a stable reference orientation with respect to which the motor target position is defined.

3.2.2 Motor Control and Communication (Computer 1)

This software acts as an interface between the microcontroller software, the simulation software, and the sound synthesis software. It communicates with the first software according to the Xbee API v2 protocol, with the latter two programs via OSC. This software passes on information about the motor's current position and speed to the installation software and sound synthesis program. From the simulation software it receives information about the motor's target position and speed. This information is divided into multiple motor control settings that are then scheduled and sent sequentially to the microcontroller in order to guarantee a safe accelerate or deaccelerate of the rotating platform.

3.2.3 Video Tracking (Computer 1)

The sequential processing steps of the video tracking software are depicted in Figure 3. The software retrieves a distance image based on the current point of view of the tracking camera. It also retrieves a second distance image by extracting a section from one of several previously stored panoramic distance images that represent virtual spaces. The location of this section within the panoramic distance image is controlled by the current position of the motor. These two distance images are averaged into a merged image. The merged image is then subjected to two different post-processing pathways. One calculates a horizontal and vertical gradient to be directly passed to the simulation software. The other calculates averaged values of several columns located in the center region of the merged distance image. These values are sent via OSC to the sound synthesis software.

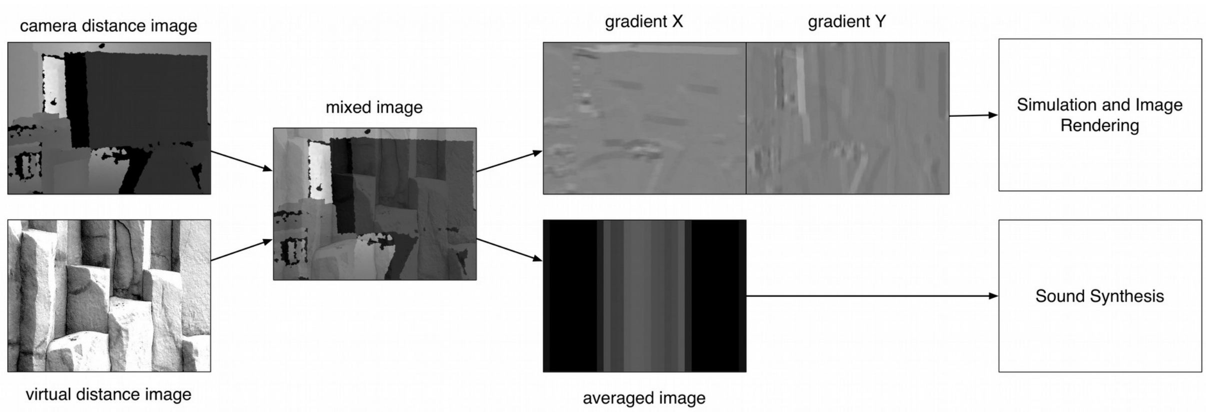

Figure 3. Image processing. A schematic representation of the image processing steps that are applied to the two distance images prior to their usage as inputs for the simulation, image rendering, and sound synthesis routines.

3.2.4 Simulation and Visual Rendering (Computer 1)

This software forms the core part of the installation. Its controls the simulation algorithm, the visual rendering, and the kinetic movements of the installation. It also controls the global states of the simulation, each of which is associated with a particular image of a "virtual space" as well as a certain set of parameters for the simulation and visual rendering. State changes are always triggered at a predefined angle. In addition, some parameters are variable depending on the direction and speed of the motor’s rotation and on whether visitors are present within the view of the tracking camera.

The simulation implements a particle system in which each particle possesses the following properties and behaviours: a mass, a preferred velocity, and a preferred speed. The particles experience drag and perturbations effects. They can sense the horizontal and vertical gradients derived from the distance image as slopes that oppose or propel their movement. By laying down virtual pheromone marks, the particles can sense neighbouring particles and either be attracted to them or evade them. As a result, the particles are able to move on their own or as groups with a limited degree of autonomy. Yet this autonomy is influenced and possibly superseded by the effects that the gradients exert on the particles’ movements. These effects typically lead to a accumulation of particles in front of an inclination, a scattering of particles along a decline, or a splitting of a groups of particles at a corner of an inclination. The particles' sensitivity to image gradients can be adjusted in such a way that they respond either to only very steep gradients or to both steep and shallow gradients. A high responsivity to steep gradients accentuates the effect of sharp corners and edges which are predominantly present in the surfaces of the walls of the exhibition space (see Figure 5 top left image). A high responsivity to shallow gradients strengthens the influence of smoother surfaces such as the ones being provided by the visitors (see Figure 5 bottom left image). In order to be able to run the simulation with several hundred thousand particles, all the behaviours and simulation routines have been implemented as OpenCL kernels that are being executed on the GPU.

The simulation and visual rendering of the particles are tightly related. Each particle is rendered as a filled circle whose only customisable attributes are its diameter, colour, and transparency. Accordingly, the characteristics of the resulting visual rendering is predominantly determined by the spatial arrangement of the particles. This arrangement is controlled by a combination of the particles own behaviours and the geometrical structures of the physical surfaces of the surrounding space (see Figure 5 for some visual renderings of the particle system).

3.2.5 Sound Synthesis (Computer 2)

TODO (Philippe)

3.2.6 Watchdog (Both Computers)

The watchdog software consists of a small python script that constantly monitors whether all the software applications are running. If an application has unexpectedly quit, the watchdog might kill additional applications if they are related to the crashed application according to an interdependency map. It then tries to restart these applications in the predefined sequence given by the interdependency map. If the restarting fails, the watchdog program reboots the computer. The watchdog program also maintains an exhibition schedule according to which it stops all applications after the exhibition's closing hours and starts them before the exhibition opens again.

4. Results

Drift has been exhibited from October 23 to December 6 2015 in the gallery *Zimmermannhaus* in Brugg, Switzerland. The schematics of the exhibition space are shown in Figure 4. Some impressions of the exhibition situation are shown in Figure 6. The gallery permitted us to setup the installation one week in advance of the opening in order to allow us to adapt and fine tune the installation to the specifics of the space.

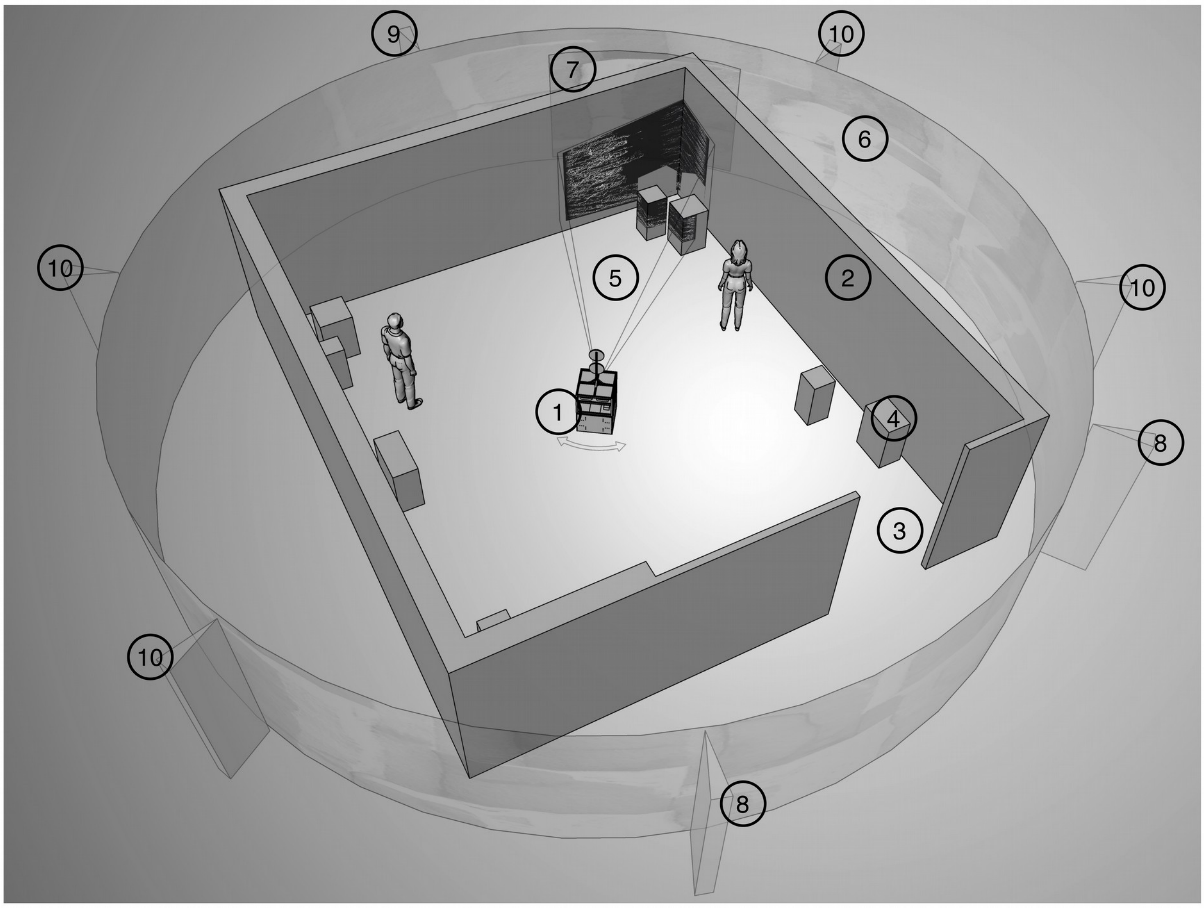

Figure 4. Installation setup. A schematic representation of the exhibition space and a surrounding virtual space. The numbering refers to the following elements: 1) the rotating platform 2) the walls of the exhibition space 3) the entrance 4) one of several pedestals 5) a frustrum representing the camera view, video projection, and audio beam 6) the distance image of a virtual space 7) a subregion of the virtual space that is aligned with the orientation of the installation 8) limit orientations for the installation rotation 9) state change trigger position for the simulation and visual rendering 10) state change trigger positions for sound synthesis.

4.1 Space, Movement and Interaction

Concerning the placement and kinetic movement of the installation, the following adaptation were made in order to take into account the layout of the exhibition space. The rotating platform was placed in the middle of the exhibition space. The central reference orientation for the motor was assigned in such a way that the installation's audiovisual output is projected onto the main wall opposite of the entrance. Due to the fact that the entrance section of the exhibition space consists of a series of glass windows, we decided to concede our plan to let the installation rotate through multiple full revolutions. Rather, we introduced limit orientations at locations beyond which the video image would be projected though the glass window (see Figure 4). Accordingly, the kinetic movement of the installation operates as follows: starting from the central reference orientation, the installation rotates either clockwise or counterclockwise. It maintains this rotation direction until it reaches a limit orientation at which it reverses direction. Whenever the installation reaches the reference orientation, the software triggers a scene change. This scene change starts as a widening of the projected image in order to cover as much of the rear exhibition wall as possible. Subsequently, a different virtual space was selected and the simulation and visualisation transitioned gradually to a new parameter set. With a brief delay, the projected image narrows down again to a narrow vertical strip and the rotation resumes. The installation's response to the presence of visitors was implemented in such a way that it causes a slowing down of the kinetic movement. This calmer mode of operation is meant to facilitate the observation of and interaction with the audiovisual superposition that manifests on the exhibition wall and the visitors' bodies. As soon as the camera view is again free of visitors, the speed of the rotation would gradually increase to its original higher value. Finally, we decided to modify the exhibition space itself in order to increase the diversity of its otherwise extremely uniform and regular wall surfaces. This small intervention involved the placement of white exhibition pedestals in front of the wall at more or less random locations. This disarrangement of the physical space led to a greater heterogeneity in the captured distance images which in turn caused the generative simulation, visualisation and sonification routines to respond in a more diversified manner.

4.2 Simulation and Visual Rendering

The principal functionality of the simulation and visual rendering software had largely been implemented and tested prior to the working phase that took place directly in the exhibition space.

The first site-specific adaptation was the implementation of a mechanism that relates the values of certain simulation settings to the rotation direction and speed of the kinetic movement. This change was considered necessary in order to establish a behavioural and aesthetic correspondence with the frequent directional changes in the kinetic movement. In the end, the main simulation parameters that were controlled by the motor's movement were the velocity and directionality of the movement of the simulated particles as well as their sensitivity to the presence of image gradients. The relation between kinetic movement and particle movement caused the particles to move in synchronicity with the surfaces of the exhibition walls and to become almost stationary during moments when the kinetic movement stopped.

The second site-specific adaptation concentrated on finding combinations of simulation parameter settings that balance the strengths of the influences of the physical space, the virtual space and autonomous particle behaviours on the visual superposition effect. Each of these combinations of parameter settings defines a scene. In the end, the variety of scenes that were created for the exhibition space represent permutations of the following parameter combinations: strong or weak influence of image gradients derived from the physical space, strong or weak influence of image gradients derived from virtual space, strong or weak autonomous behaviours that are independent of any image gradients. The images on the right side of Figure 5 depict visual renderings that correspond to some of these permutations.

Concerning the configuration of the visual rendering, it was decided early on that all particles would be rendered as small black and white circles. The only variety among the scenes that concern the visual settings are the transparency levels of these particles and small modifications of the circle radius. This decision was made in order avoid that the projected video image would deviate visually too much from the normal appearance of the white exhibition walls. Rather, the purpose of the video projection was to create a situation of superposition in which both the visual rendering and the normal wall appearance intermix with each other without any of the two dominating and superseding the other one.

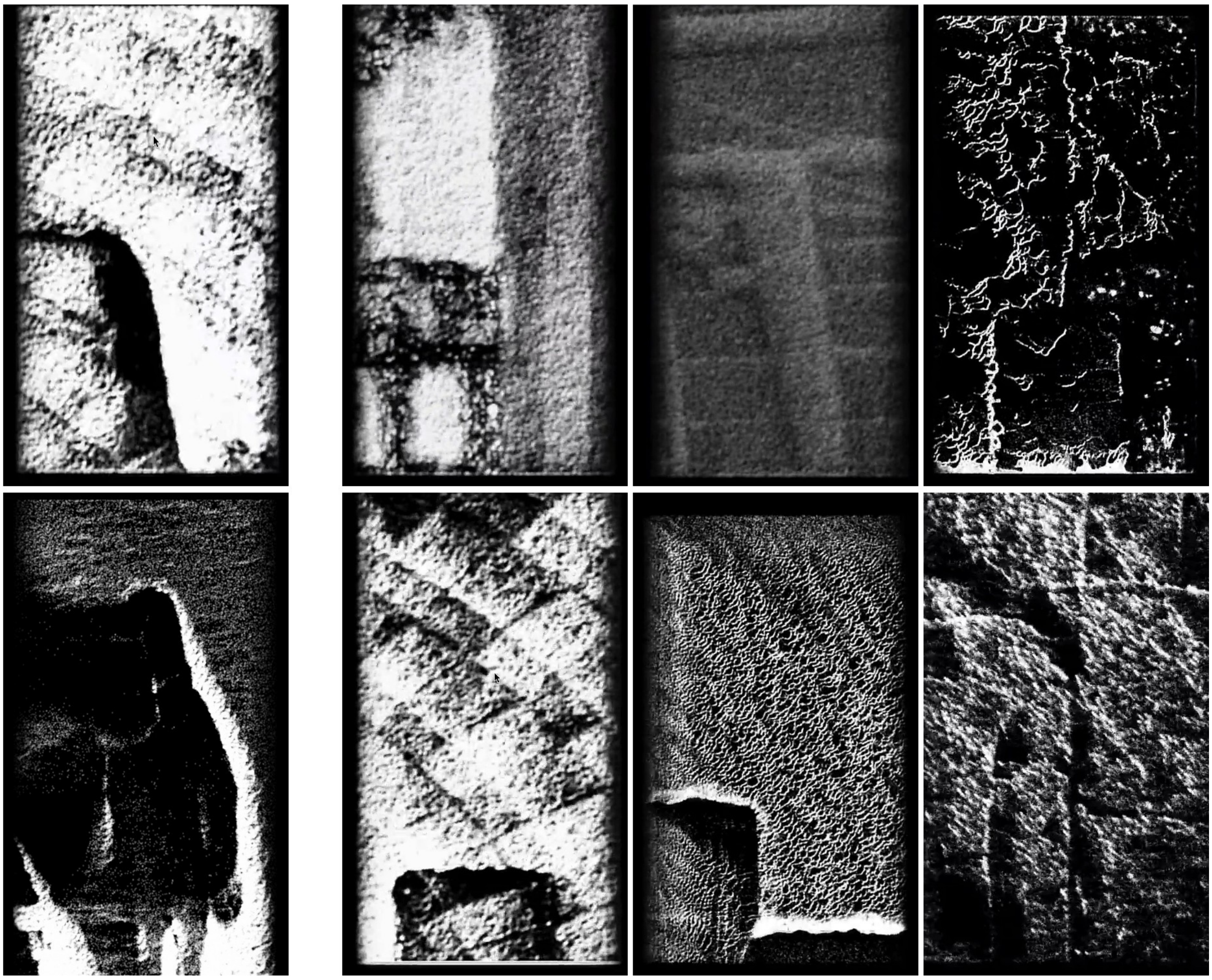

Figure 5. Visual renderings of the particle simulation. The column on the left side depicts visual renderings of the particles' response to gradient images. The three columns on the right side depict visual renderings of simulation settings that differ with respect to the strength of the effects of the physical space, the virtual space, and the particle's autonomous behaviours. Left side top image: Particle responding to the steep gradients obtained from tracked objects. Left side bottom image: Particles responding to the shallow gradients retrieved from tracked visitors. Right side top left image: strong physical space, weak virtual space, weak particle autonomy. Right side

top middle image: weak physical space, strong virtual space, weak particle autonomy. Right side top right image: weak physical space, weak virtual space, strong particle autonomy. Right side bottom left image: strong physical space, strong virtual space, weak particle autonomy. Right side bottom middle image: strong physical space, weak virtual space, strong particle autonomy. Right side bottom left image: weak physical space, strong virtual space, strong particle autonomy.

4.3 Sound Synthesis

TODO (Philippe)

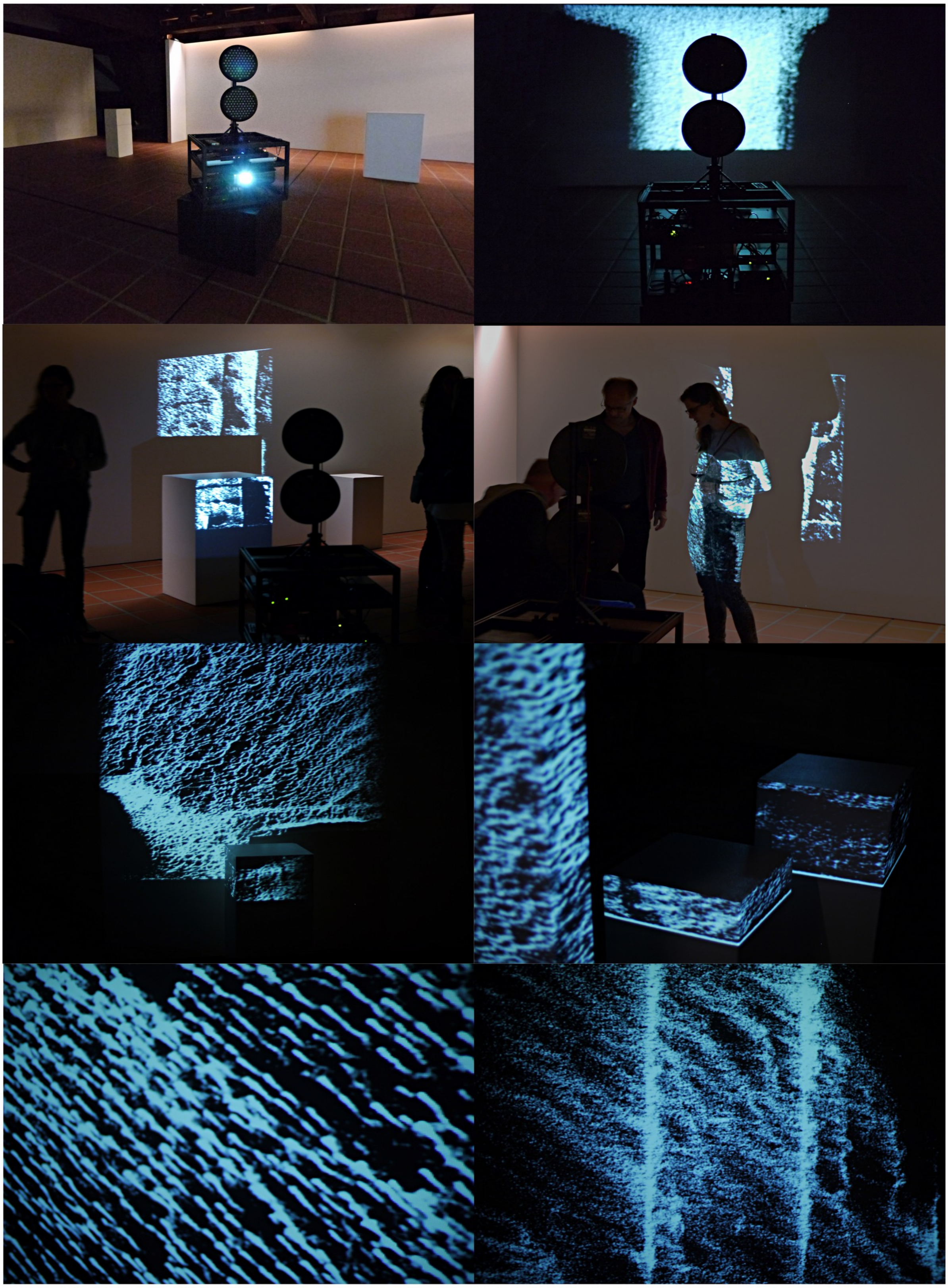

Figure 6. Exhibition impressions. The photographs have been taken during the opening of the exhibition.

5. Conclusion

The process that started with the specification of the installation concept and ended with the actual installation taking place in an exhibition space was highly interesting for us. In particular, the final week before the opening proved to be crucial for realising a tight and site specific relationship between the installation’s capability to sense and respond to the peculiarities of a physical space and the physical space’s susceptibility to accommodate the synthetic audiovisual output into its appearance. Despite the fact that surface reliefs were the only physical characteristics of the space that were used as input for the generative processes, a clear and very specific correspondence between the space, its visitors, and the synthetic audiovisual output could be achieved. The fact that this correspondence became perceivable as a superposition on the surfaces of the physical space (a space that most visitors were very familiar with because of their previous exhibition visits) strongly conveyed the concept of merging artificial and physical aspects of a space. For this reason, we believe that the installation has been successful in realising and conveying our generative approach to augmented reality.

Based on this outcome, we are interested to further proceed along this line. First and foremost, it would be interesting to setup the same installation in different spatial situations such as larger rooms, and/or rooms with more diversity with respect to their surfaces, and/or rooms that are partially open to external influences such as daylight changes or acoustic emissions. On a slightly longer timeline, it seems worthwhile to try to improve and expand the characteristics of the relationships between a physical space and its virtual augmentation. For instance, in its current version, the correspondence between the installation’s kinetic movement, the surrounding space, and interacting visitors is very simplistic. The former correspondence is static and based on a few manually determined orientation key points. The latter one is a binary rotation speed change based on a distance threshold. It would be more interesting to capture and translate in the kinetic movements of the installation more distinguished and continuous aspects of the physical space and the interacting visitors.

An expansion of the relationship between a room’s characteristics and generative processes can also be achieved by capturing and analysing a wider range of physical qualities. With the addition of a simple infrared camera, the light situation in the room could be taken into account. Changes in the light situation, whether caused by sunlight that enters the space or by visitors manipulating light switches, could be used as explicit inputs for the simulation and rendering processes. The acoustic properties of the space could also be taking considered, for instance by conducting impulse or frequency response measurements in order to acquire information about the room’s acoustic characteristics. This information could then be used to change the sound synthesis methods and thereby produce a space specific sonic result.

To conclude, we would like to express our conviction that generative approaches to augmented reality provide an exciting avenue for artistic creation. This artistic activity provides an opportunity for practitioners in generative art, installation art, and augmented reality to collaborate based on a common ground of interests.

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