Light fountain – a virtually enhanced stone sculpture

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ABSTRACT
The article describes the making of an art piece combining stone sculpture and virtual water. The motivation for this art piece was to enrich the usual static format of a stone sculpture with a dynamic dimension. The dynamic dimension is attained with virtual water droplets running over the stone surface which behave as real water droplets. The 3-D surface of a specially carved stone sculpture is during an exhibition continuously captured by the Kinect sensor. Each water drop out of many thousands, which are introduced into the installation as evenly distributed rain drops, falling over the sculpture, are simulated individually to run over the stone surface following the largest slope. These simulated water drops are projected with a video projector as light points on the surface of the sculpture. An observer can enjoy simultaneously the haptic experience of touching the stone and observing a digitally generated but physically grounded animation.

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1. Introduction

Artists often try to integrate movement into paintings and sculpture to make their art more alive and engaging. Paintings that strive to communicate some movement typically have to rely on some special painting style or optical illusions such as in 'op art'. Sculpture, on the other hand, could in fact include actual physical movement of its constituent parts. Mobiles are typical examples of kinetic art that react to gravity and atmospheric conditions. Mobiles are, therefore, usually made out of metal, wood or other materials that are malleable enough to form light and strong parts.

Other types of kinetic sculpture react to spectators who can directly manipulate components of the sculpture or who can activate directly, or by means of some sensors, motors that animate the sculpture. This type of art has evolved also into interactive computer-based installations that typically react to the presence and movement of visitors.

Introducing physical movement into stone sculptures is, on the other hand, much more difficult due to their massive and heavy forms. Only stone spheres, due to their geometry, can be moved around without excessive force as manifested by David Fried's kinetic sculptures entitled 'Self Organizing Still Life' (Fried 2011). Fried places in his project several spheres on a level enclosed surface. Every sphere is of a different size and material such as solid rock, sand or synthetic polymers. The spheres are activated by ambient sound. The movement and interactions between Fried's spheres represent how the universe is interconnected. The technology is not explained, but microphones are probably used to detect the ambient sound and activate electro-magnets in the base of the installation to trigger the movement of the spheres (Brockmeyer and Marsico 2014).

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However, an age old way of making stone sculpture more dynamic and energetic is to combine stone with running water. This is manifested by the abundance of fountains made out of stone throughout history in all parts of the world. A nice example of combining granite and running water is the contemporary sculpture 'Stone of life' by Janez Lenassi in Ljubljana which was finished in 1978 (Figure 1).

Another well-known fine art sculpture which has been enhanced with running water is the sculpture 'Water stone' by Noguchi (1986) installed inside the Metropolitan Museum of Art in New York. However, the majority of stone sculptures incorporating running water are placed outside due to practical reasons of handling excessive water.

1.1. Motivation

To evade the problem of handling running water inside buildings we decided to animate a stone sculpture not with real water but by using virtual water droplets generated by modern computer technology. Our original intention was that this virtually enhanced art piece would be appreciated by the public primarily by observation.

To make the animation realistic one needs to know the actual 3-D shape of the stone sculpture. In recent years methods for capturing 3-D shapes have become much faster and easier to use. Low-cost sensors such as the Microsoft Kinect have opened the door to new applications where the 3-D shapes of objects and their location in a scene have to be known.

The Kinect sensor was originally developed for gaming applications but it was soon co-opted by scientists and artists for all kind of applications, especially if some sort of interaction is required as in computer games (Zhang 2012). An overview of some artistic applications of Kinect can be seen on the Creative Applications Network website (Creative Applications Network). Even the infrared light itself, used by the Kinect sensor and invisible to the human eye, was used in an art photography project 'Dancing With Invisible Light' (Penven 2011).

In this article we describe how the Kinect range sensor was used to continuously capture the 3-D shape of a stone sculpture so that virtual water droplets falling on the sculpture can be simulated to behave as real water droplets, which are then projected as light points on the physical stone sculpture, using a video projector. The resulting art piece was entitled 'The light fountain'. A preliminary report on this project has already been presented at a conference (Meden et al. 2015). In this preliminary report only the technological side of the project is described since the sculptural part was not finished yet.

(a)

(b)

Figure 1. (a and b) Granite fountain entitled 'Stone of life' by sculptor Janez Lenassi, finished in 1978, stands in the 'Žale' cemetery in Ljubljana.

1.2. Related work

Projects which are from the technical aspect most related to our goal are interactive sandboxes (Reed et al. 2014; SandyStation) where users can shape the sand in a sandbox into new forms which are continuously captured by a Kinect sensor. A video projector is used to colour the sand according to its height and configuration. These boxes are primarily intended for educational purposes, demonstrating geographic, geologic and hydrologic concepts such as how to read a topography map, the meaning of contour lines, watersheds, catchment areas, levees, etc. The sandboxes, however, can also be a platform for interactive games (Reed et al. 2014; Mimicry). The virtual space projected onto a physical 3-D landscape becomes alive with a multitude of living forms ranging from spiders, beetles and snails through ammonites and trilobites to sharks and dinosaurs, all inhabiting a mixed reality ecosystem (St. Jean 2012).

In fine art sculpture there is already some tradition in using virtual models of 3-D forms. Physical sculptures, for example, can serve as key-shapes for a series of virtual sculptures which can be exhibited in parallel (Adzhiev, Comninos, and Pasko 2003). The virtual shapes are first overlaid on the physical sculptures but next they can evolve in an interactive sculpting session. A Kinect sensor can also be used as an aid for real-time pose editing different kinds of articulated sculpture artworks (Wu et al. 2016). In a digital heritage scenario, skeletons of statues or of human bodies which are captured by depth sensors for mobile devices can be used to query datasets of 3-D models of Graeco-Roman statues (Barmpoutis, Eleni, and Daniele 2015).

Fascination with running water is also evident in the 'Waterfall' animation for the Salesforce lobby in San Francisco (Obscura 2016), which involves simulation of water running across a horizontal plane and over a vertical lip to achieve spectacular visual effects on the walls of the lobby. The visualisation reflects the local weather, so that, for example, when it snows outside, it also snows on the screen.

French designer Mathieu Lehanneur has created a series of sculptures, called 'Liquid Marble' out of dark marble whose top surface is carved in the form of wave ripples. When an observer is moving around such a sculpture the changing light reflections from the carved marble surface induce the semblance of moving waves. The surface is designed first with 3-D modelling software, which is then used to guide a stone carving machine and, finally, the resulting marble surface is hand polished (Lehanneur 2016).

1.3. Technical requirements

To create an art piece, where virtual water droplets are running on the surface of a stone sculpture, we had to address the following technical problems:

1. carving of an appropriate stone sculpture with rather level and continuous surfaces so that the video projection is not discontinued by self-imposed shadows;
2. capture of the 3-D shape of the sculpture's surface on which light points representing water droplets are simulated;
3. creation of a dynamic model for water droplets which, according to the law of gravity, run down the maximum slant of the sculpture's surface;
4. alignment of the 3-D model of the sculpture, acquired by Kinect, with the video projection of the virtual water droplets, and the actual stone sculpture.

The rest of the article is divided as follows. In Section 2 we describe the stone sculpture that was carved especially for this project. In Section 3, the implementation of the virtual part of the art piece is described. In Section 4, the resulting art piece is presented, reactions of the public confronted with the art piece during the first public exhibition are reported and possible improvements of the art piece are considered. Section 5 discusses the resulting art piece in a wider context of interactive art and concludes the article.

Figure 2. Initial design on top of the marble block of Macedonian Sivec stone which was inspired by sun rays emanating in a spiral shape from a focal point.

2. The stone sculpture

A stone sculpture designed especially for this project has been carved by the first author of this article out of a block of Macedonian Sivec marble (Figure 2). Sivec is a dolomitic marble that was used in south-east Europe from the third century BC until the fifth century AD, producing some of the most visually stunning creations of the ancient world (Prochaska 2013). The marble block has approximate dimensions of $40 \times 60 \times 20$ cm. During the stone carving process we have continuously tested the shape of the top surface with real water to test if the slant was sufficiently large to allow water to run towards the edges of the sculpture (Figure 3). The top surface is smoothly undulating resembling curved sun rays emanating from a central point, somewhat reminding one of the Vergina Sun (Danforth 2010) (Figure 4). The marble surface of the sculpture was not polished to a high gloss so that the projected light points can be absorbed in the material rather than specularly reflected, making in this way the projected light points more clearly defined.

3. Implementation of the virtual part of the art piece

To capture the 3-D shape of the sculpture Kinect for Xbox 360 is used, which is a Microsoft product that captures 3-D points on the principle of using an infrared projector and an infrared camera (Zhang 2012). Kinect appeared together with the game console Xbox 360 primarily to capture the movement of players of computer games. But since Kinect is easy to use and is reasonably priced it became popular with a large user community that applies Kinect to a large variety of applications that need 3-D shape capture (Develop Kinect). The output of Kinect is a cloud of 3-D points in a given coordinate system. It has a built-in gyroscope so that the vertical axis can be aligned with the direction of gravity.

For projection of light points representing the water droplets a video projector is required. Any digital video projector with a high resolution and a zoom lens, so that the projection

Figure 3. The slant of the top surface of the sculpture was tested with real water.

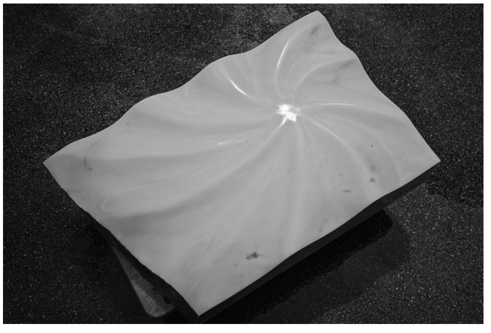

Figure 4. The finished stone sculpture carved particularly for the project 'Light fountain'.

angle can be adjusted, is adequate. The video projection of animated light points, whose movement is computed based on the 3-D shape of the sculpture's surface, which is captured by Kinect, must be projected on the actual surface of the sculpture.

To facilitate the 3-D surface capture and the projection of virtual water droplets on the sculpture, the Kinect and the video projector should be mounted above the sculpture close together and with their lines of sight almost parallel so that all parts of sculpture's surface are visible from their viewpoints. To securely install both devices above the sculpture a heavy-duty tripod is used, with a custom-designed mount for the video projector and the Kinect (Figure 5). Since the accuracy of the Kinect sensor drops with larger distances, the distance between the sculpture and the Kinect must not be too large. Experiments show that the accuracy of Kinect at a distance of about 1.5 m is in the order of just a few millimetres (Ravnik and Solina 2013). However, the variation in depth estimate when Kinect is pointed directly at a planar surface is larger and not entirely random and it appears like a circular ripple in the depth image (Andersen et al. 2012). This problem can sometimes manifest itself when on a part of the surface, with a very small slant, the simulated droplets are not running towards the lower parts and the edges of the sculpture.

In the current hardware configuration, the Kinect has a wider field of view as the video projector. By experimentation it was determined that when the Kinect and the video projector are mounted about 120 cm above the sculpture, a good compromise is reached for sufficient accuracy of the Kinect and also for the video projection since at that distance and at the given size of the sculpture, the whole resolution of the video projector can be used.

(a)

(b)

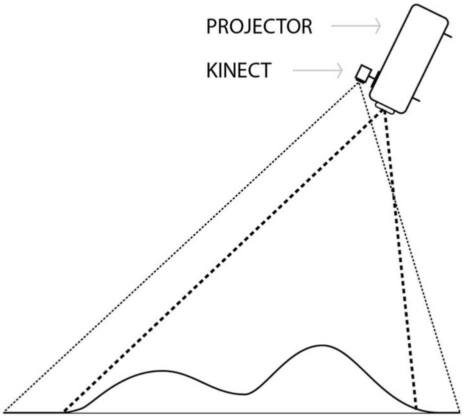

Figure 5. (a and b) The setup of the equipment: the video projector and Kinect are aligned and close together about 120 cm above the sculpted stone surface.

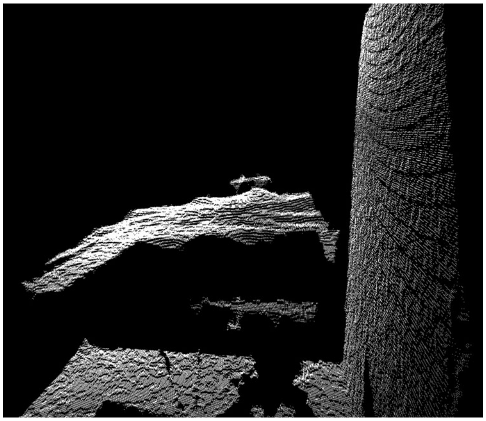

Figure 6. A cloud of 3-D points captured by Kinect: the sculpture is seen from the side.

3.1. 3-D model of the sculpture

The 3-D point cloud, representing the 3-D shape of the sculpture, obtained by Kinect is defined in a coordinate system which is rotated according to the slant of the Kinect sensor (Figure 6). The 3-D point cloud must therefore be transformed with an inverse rotation into a global coordinate system where the actual sculpture also resides. The slant of the sensor is indicated by the gyroscope which is built into the Kinect. It is possible also to manually set the slant angle on the user interface of the system. The 3-D points after the transformation are aligned with the global coordinates of the work space. The global coordinates represent the following dimensions: z-axis, vertical dimension or the direction of gravitation; x-axis, first dimension of the horizontal plane; y-axis, second dimension of the horizontal plane.

The captured cloud of 3-D points in Figure 6 is first reduced by a manually defined mask only to those 3-D points that lie on the sculpture. The resulting 3-D points are then transformed into an intensity image by projecting the 3-D points onto the horizontal plane (Figure 7). This gives us the perpendicular view of the scanned sculpture. From the intensity image we generate the 3-D model of the sculpture (Figure 8) which represents the supporting surface and is used for the computation of the movement of individual water droplets. The 3-D model of the sculpture's surface is a grid of points where the coordinates of each 3-D point are the x and y coordinates of the corresponding pixel in the intensity image and the z coordinate is the intensity (height) of the pixel. This 3-D model in Figure 8 represents the surface of the scanned sculpture.

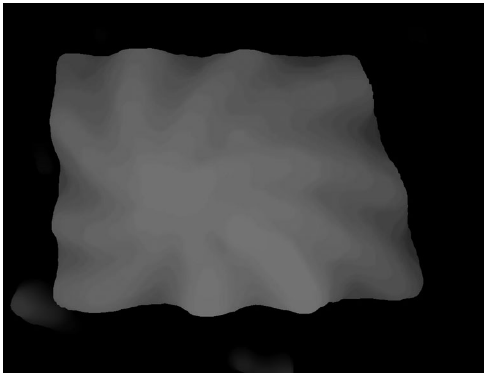

Figure 7. A range image shown as an intensity image where the intensity of each pixel corresponds to the distance from the Kinect sensor: the undulated surface is seen in a top-down direction.

3.2. Software environment

OpenFrameworks is an open source framework for integration of various technologies which are used in computer graphics, computer vision and in interactive applications in general. The framework is written in C++ programing language and represents a high-level abstraction of OpenGL, GLEW, Glut, FreeType, OpenCV and other libraries. The framework enables the use of different libraries which are developed by an active community of developers. Beside OpenFrameworks we used in the project also the following two software libraries: ofxKinect, which supports communication with the range sensor Kinect, and ofxGui, which offers elements for adjusting the user interface parameters.

Microsoft Visual studio is an integrated development environment which supports the C++ programing language and is the recommended tool for application development under OpenFrameworks on the Windows operating system.

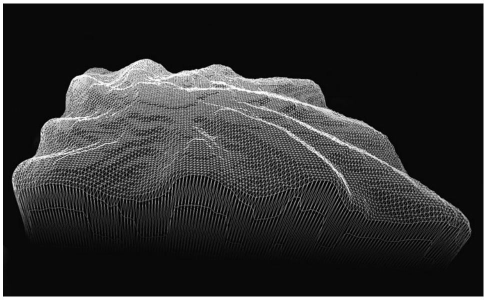

Figure 8. The 3-D model of the sculpture's surface used in the simulation of the movement of water droplets: seen from the side. The surface is divided into a grid of approximately 150×230 cells.

The system must support the processing of the input image and the simulation of water droplets which is computationally very demanding and proportionally dependent on the number of simulated water droplets. We use a PC computer which makes possible a simultaneous simulation of 50,000 water droplets at the speed of 30 frames/s. This enables a reasonably good approximation of liquid simulation.

Since the Kinect sensor refresh rate (from 20 to 25 Hz) is a bit slower than our simulation loop refresh rate (i.e. the application's frame rate is from 30 to 40 FPS), we designed the application to run in two parallel sections using threads. In the main thread we perform rendering (since the underlying OpenGL library has a client–server architecture and therefore works optimally only on one thread) and the particle update phase (which is closely related to the render phase). The secondary thread continuously reads the depth data from the Kinect sensor and performs all data transformations. It also calculates the gradients, which are needed to properly simulate water particles in the main thread. This also means that both threads have to cooperate in order to share the depth and gradient data between each other. Since the application is coded in C++, we can optimise the crucial data sharing and memory locks by using a double buffering technique. In this way, we share/lock only the pointers which point to the shared data and the data themselves are not moved or copied around; therefore we can be more effective in terms of speed and inter-thread communication.

3.3. Simulation of water droplets

Since we could not find an appropriate open source solution for the simulation of water droplets that move in the direction of the highest gravity gradient, we decided to write our own code.

To visualise the running water on the surface of the sculpture, a large number of small particles in the form of spheres that move across the surface of the 3-D model are used. Each particle or droplet is a single unit that moves independently and is also independently simulated. The entire simulation of water proceeds in loops. Approximately 30 such loops are executed each second to achieve the appearance of smooth motion. In each loop the direction and velocity of the movement of all droplets are updated. The computation of the movement of each droplet depends on:

1. the gradient of the surface at the actual position of a droplet;
2. the direction and velocity of the droplet in the previous step of the simulation;
3. an adjustable chance factor.

After new gradients are received from the secondary thread, the simulation loop goes over all existing particles and updates the velocity of each particle according to its position on the surface, taking into account the previous velocity vector and refreshed gradient values. The entire simulation is performed for each video frame so that all water droplets are redrawn in their new position.

A droplet therefore moves across the sculpture according to the slant of the surface. Since a droplet has a mass, the inertia from the previous step influences its movement in the next step of the simulation. Individual droplets however do not have any physical dimension and therefore no collisions between droplets are computed. The detection of such collisions is computationally demanding and if performed, it would reduce the maximum possible number of droplets that can be simulated on our hardware in real time. We also do not use any additional shading and illumination of droplets which is also computationally demanding and does not add much to the desired visual effect.

Droplets must come from somewhere in order to run down the sculpture. Water droplets can be introduced into the simulation in two possible ways:

1. as rain drops falling evenly distributed over the whole surface of the sculpture or

2. from possibly several water springs on the surface of the sculpture. The user interface enables the user to define the position of water springs on the sculpture interactively. Water springs are useful for testing the behaviour of water droplets in a particular part of the sculpture (Figure 9). One can select several springs; however, the number of water droplets is then divided among them so that the simulation always uses the same predefined number of water droplets. If the maximum possible number of droplets in the current implementation (50,000) is divided among 10 springs one can still get a realistic visualisation.

Droplets disappear from the simulation when they reach the edges of the sculpture. They are reintroduced again as new rain drops falling on the sculpture or as water drops in one of the springs. In general, the best visual appearance of the art piece is achieved in the 'rain' mode of operation (Figure 10).

The large number of moving droplets creates the appearance of running water. Since a large number of droplets can reappear in the same point of the 3-D model and continue to move according to the surface gradient, a chance factor is used, which takes care that the path of water droplets originating from the same point is not identical. This chance factor greatly improves the appearance and is computationally not demanding.

Figure 9. Water droplets can emerge from springs, which can be interactively defined on top of the sculpture. This functionality was useful during the preliminary testing of water droplet behaviour.

3.4. Spatial adjustment of video projection and the projection surface

When the whole installation is being set up, the first task is to align the picture projected by the video projector to the projection surface on the sculpture. The picture is initially approximately aligned based on the position of the Kinect and on the centroid of the 3-D points. The virtual camera in the simulation model is positioned in the point where the Kinect is mounted and directed towards the centroid of all 3-D points captured by Kinect (approximately towards the projection surface).

However, Kinect and the video projector cannot be exactly in the same physical position as shown in Figure 5 and, therefore, they cannot have exactly the same viewing angle. This difference must be adjusted manually. This can be done on the user interface by changing the projection angle and the scaling of the 3-D surface model. One can also manually adjust the edges

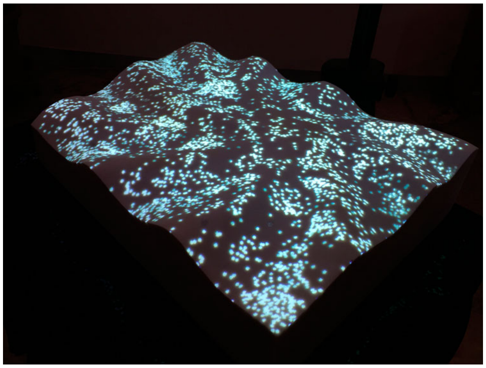

Figure 10. Final appearance of the art piece entitled 'The light fountain' showing water droplets/light points raining evenly over the whole sculpture, collecting and running down the sloping channels towards the edge of the stone sculpture. For an animated view see the following link on YouTube: https://youtu.be/nqituTE-_SI.

of the projected animation so that the water droplets are projected only on the surface of the sculpture.

3.5. User interface

During the simulation of water droplets the user can change different parameters of the simulation using a simple graphical user interface (Figure 11).

On the user interface one can change the following parameters of the simulated water droplets:

- the number of droplets in the simulation
- the viscosity of the droplets
- the value of the chance factor for the movement of the droplets
- colour of the droplets
- transparency of the droplets
- background colour
- addition and removal of water springs on the surface of the sculpture
- selection of the operation mode (rain/water springs)
- other positioning and diagnostic parameters.

4. Results

We have experimented with different settings for colours and appearance of light points but settled at the end for a rather minimalistic appearance using just white light points on a dark background (Figure 12). A video clip of the installation can be seen on YouTube (Solina 2015a).

The art installation was exhibited for the first time at the ARTIUM SPECULUM 2015 Festival of new media culture in Trbovlje, Slovenia, which was in 2015 running under the motto 'The Integrity of Reality' (AS 2015). The exhibition space was kept in semi-darkness so that the outlines of the stone sculpture could still be discerned but the emphasis was on the projected light points (Figure 12). Actually, the shape of the underlaying stone surface could be easily inferred from the movement of the light points even in total darkness.

The installation was warmly received by the public. Since the original intention of this art piece was to virtually enhance a stone sculpture and to observe the simulated flow of water, it was somewhat surprising that most observers also wanted to touch the sculpture and to interact with the moving light points. Visitors were henceforth encouraged to touch the sculpture and it seems that this merging of haptic and visual experience was an additional attraction of this art piece (Figure 13). By reaching into the projection cone of the installation, the public quickly realised that the rain drops instantly adapted to the changing shape of the rained-on surface. The water droplets then start to flow down the new obstacle as can be observed in a video (Solina 2015b). One can even catch light points as water droplets into the open palms of our hands (Figure 14). This interactivity is the main reason why a continuous capture of the sculpture's 3-D shape by the Kinect sensor is necessary. Although the stone sculpture itself is static and it would suffice therefore to capture its 3-D shape just once, when the installation is being set up, the interactive nature of the installation would be lost without the continuous 3-D shape capture.

Children were especially happy when they discovered that they can 'splash' with light points, but they also voiced a factual observation that the light points resemble tiny styrofoam balls rather than water droplets.

Some observers related their experience that watching the installation is somehow hypnotising and that it is difficult to turn away one's gaze.

4.1. Possible improvements

The model for water droplets used in the described installation is fairly simple. The behaviour of water droplets depends mainly on the gradient of the 3-D surface. The velocity of each water droplet is individually computed.

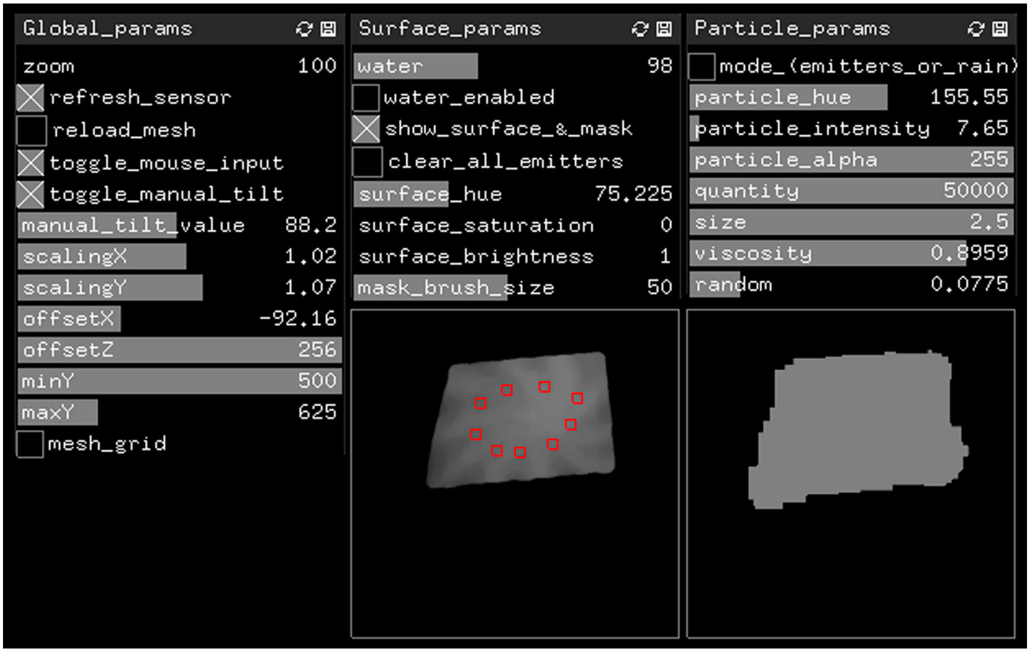

Figure 11. User interface for adjusting the parameters of the water drops simulation.

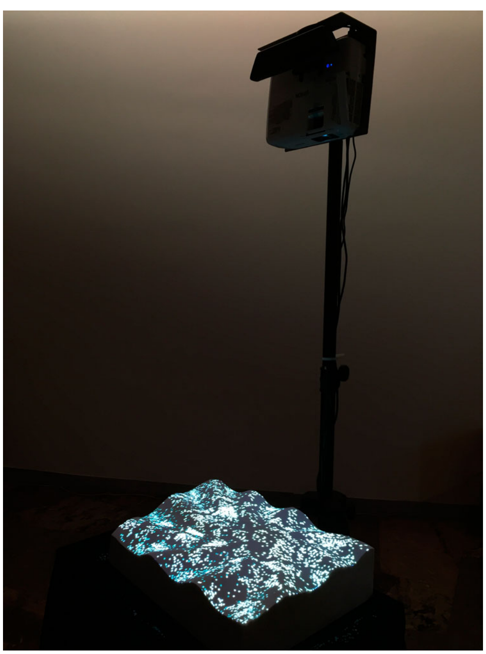

Figure 12. Art piece 'Light fountain' at its first public exhibition at Speculum Artium 2015, festival of new media art in Trbovlje, Slovenia, in October 2015.

In each simulation loop the velocity of individual droplets increases or decreases depending on the gradient of the surface.

One could use one of the existing simulation packages for liquids. A suitable open source simulation package is Fluids v.3.1[1] which offers support also for a parallel implementation based on CUDA technology.[2] With this package one could increase the number of simulated droplets and make the simulation more

Figure 13. The virtual rain drops are inviting the observers to interact with them and to touch the sculpture.

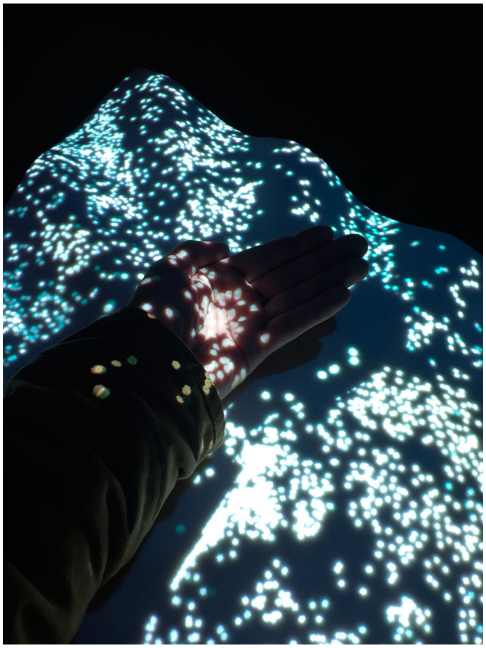

Figure 14. Kinect takes range images continuously so that when an observer reaches into the projection cone, the virtual rain drops start to collect in her open palm.

realistic. Interaction between droplets could be modelled, as well as the interaction of droplets with the supporting 3-D model. However, a much more powerful computer would be required to run the simulation.

One could also improve and speed up the process of properly aligning the optical axes of Kinect and the video projector. Some temporary markers, for example small spheres at the edges of the sculpture, would simplify the iterative adjustment of the direction of both optical axes and the zoom settings of the video projector so that the 3-D surface model obtained by Kinect, on which the simulated water droplets are moving, would match more closely the physical surface of the stone sculpture.

The same virtual enhancement could be applied also to a much larger sculpture. However, the range scanner would have to be moved further away from the surface of the sculpture, in this way making the Kinect ill-suited since the errors in depth assessment would become too large. Some other range scanner would be required in such a case, while the selection of a video projector is not critical.

5. Discussion and conclusions

Computer-mediated interactive art installations receive signals from the environment and the observers; they process the signals to transform the installation according to these signals typically into a new visual form which is then 'exhibited' (Edmonds, Bilda, and Muller 2009; Strehovec 2009). Cornock and Edmonds (1973) defined four basic categories that characterise the relationship between artwork, artist, viewer and environment which are particularly applicable to interactive artworks. These four categories are:

1. Static: There is no direct interaction between the artwork and the observer, as when an observer is looking at a painting. The observer, however, may experience some emotional or psychological reaction.
2. Dynamic-passive: The art piece can change in a predictable way to outside environmental influences (light, sound, temperature). The observer is a passive observer of these changes. All possible changes of the art piece are predefined by the artist.
3. Dynamic-interactive: It is the same as dynamic-passive with the added factor that observers can also assume an active role in influencing the changes of the art piece, nowadays achieved usually using various computer-based sensors. Such art pieces can react, for example, not only to general motion but also to specific gestures of the observers, in this way making the organisational configuration of the art piece even more rich and complex.
4. Dynamic-interactive (varying): In this category an additional modifying agent takes the role of changing the initial configuration or behaviour of the art piece. The performance depends therefore not only on the current influencing signals but also on the

previous signals, which means the entire history of interactions. The interactive art piece in this way learns and evolves from experience. The modifying agents can be human observers or the art piece itself. Modern machine learning methods and access to big data over the Internet are making such art pieces highly complex but also much less predictable.

The mental process that takes place when an observer confronts an art piece can therefore already be considered as an interactive process in the sense that the mental process in the observer is a response to an art piece. With the advent of computer technology and evolution of new media installation art this primary reaction to engagement with art can be additionally mediated by computers. Various sensors, cameras in particular, are used in this perception loop that makes possible a wide variety of additional interactive interventions that can be more directly observed and experienced by the observers.

In our research team we have produced in the past several interactive art installations where the interactive intervention of observers can range from a simple presence of a human observer in the view range of a camera to active and purposeful physical actions initiated by a visitor. In the installation '15 seconds of fame', a camera is used to detect the presence of observers to be able to turn the images of their faces into pop-art portraits (Solina 2004). In the installation 'School for cats', a user directly manipulates pieces of a jigsaw puzzle on a touch screen, where the images for the puzzles were made by a person with severe learning difficulties and the installation itself is intended foremost for art therapy (Pavlin et al. 2015). Both installations can be classified as dynamic-interactive.

What is the nature of the interaction in the 'Light fountain' art installation? The signals from the environment that the system catches and processes are the 3-D shape of the stone sculpture and any obstacles above the stone's surface. This function is performed by the Kinect depth sensor. Water droplets that appear as rain in the installation are represented by light points which are generated by the computer system in such a way, as if actual water droplets would run down the faces of the sculpture. Each water droplet among the current 50,000 droplets is simulated independently and its behaviour is dependent on its previous state and the slant of the corresponding surface patch. This loop runs without a human intervention, even when nobody is present, designating it as a dynamic-passive art piece. However, an observer can always intervene in this loop by reaching with her hand into the space above the sculpture, modifying in this way the 3-D shape detected by Kinect and provoking in turn a change in the flow patterns of simulated water droplets. This is possible because the 3-D shape is continuously monitored by the Kinect sensor. This aspect gives the art piece a dynamic-interactive nature since observers can also manipulate the flow of virtual water drops, adding in this way also an interactive dimension to the primary experience of pure observation.

We have demonstrated with this project how the Kinect sensor can be used to virtually enhance a stone sculpture with a physically plausible animation, which is a novel use of Kinect in interactive art. We hope that we have in this way successfully fulfilled our initial intention to make a static stone sculpture more dynamic and alive using virtual water droplets instead of actual water.

Notes

1. http://www.rchoetzlein.com/fluids3
2. http://www.nvidia.com/object/cuda_home_new.html

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No potential conflict of interest was reported by the authors.

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