

# Interactive Spatial Multimedia for Communication of Art in the Physical Museum Space

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## ABSTRACT

This paper discusses the application of three spatial multimedia techniques for communication of art in the physical museum space. In contrast to the widespread use of computers in cultural heritage and natural science museums, it is generally a challenge to introduce technology in art museums without disturbing the art works. This has usually been limited to individual audio guides. In our case we strive to achieve holistic and social experiences with seamless transitions between art experience and communication related to the artworks.

To reach a holistic experience with minimal disturbance of the artworks we apply three spatial multimedia techniques where the only interaction device needed is the human body. The three techniques are: 1) *spatially bounded audio*; 2) *floor-based multimedia*; 3) *multimedia interior*. The paper describes the application of these techniques for communication of information in a Mariko Mori exhibition. The multimedia installations and their implementation are described. It is argued that the utilization of the spatial multimedia techniques support holistic and social art experience. The multimedia installations were in function for a three and a half month exhibition period and they were approved on beforehand by the artist to be in concordance with the artworks.

**Categories and Subject Descriptors:** H.5.1 [Information Interfaces and Presentations]: Multimedia Information – augmented reality, audio output H.5.2. User Interfaces - theory and methods.

**General Terms:** Design, Experimentation, Human Factors

**Keywords:** Interaction design, spatial multimedia, user experience, art museums, communicating art, directional audio, body as an interaction device.

## 1. INTRODUCTION

The research behind this paper has taken place within the context of a real museum setting, ARoS ([www.aros.dk](http://www.aros.dk)) a prominent art

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museum in Denmark. The museum had the ambition to try out a new way of communicating art in the physical museum space. The museum abandoned audio guides and PDAs, because they found these means of communication too isolating for the individual visitor and too detached from the actual art experience. Instead they engaged a group of experience designers and interaction designers (including the authors who do research in these areas) to develop a new art communication experience for a specific exhibition - an exhibition with the Japanese artist Mariko Mori.<sup>1</sup> This exhibition was chosen as the target for developing new communication experiences, since Mori's art per se integrates several forms of digital technology. The artist agreed to this new form of communication, and three of the museum's curators participated in the development of the art communication installations. The artist participated in the production of audio tracks for the installations. The resulting installations were also reviewed by the artist herself prior to the opening of the exhibition. During this review one piece of audio, which she found in conflict with her overall ideas of the exhibition, was removed. The rest of the installations she found to be in concordance with her art expression.

The development process for the Mori exhibition was considered an experiment to assess the feasibility of more general changes of communication means in the ARoS museum space. As researchers we took the opportunity to investigate and develop new interactive spatial multimedia technologies targeted at art museums.

We use the notion of “interactive spatial multimedia” to denote interactive multimedia integrated in the physical architectural environment, i.e. modern instantiations of Krueger's classical Responsive Environments [19]. We propose three specific techniques suitable for art museums. These techniques will be further explained in section 3.

In order to evaluate the project, a qualitative as well a quantitative evaluation has been conducted. In this paper, we only summarize this evaluation in section 5. The full documentation can be found in [16].

The paper is structured as follows. Section 2 briefly reviews previous approaches to multimedia communication in museums. Section 3 introduces the spatial multimedia techniques we propose for art museums. Section 4 describes in detail how we applied these approaches for the Mori exhibition. Section 5 summarises the lessons learned. Section 6 compares the proposed

<sup>1</sup> [http://en.wikipedia.org/wiki/Mariko\\_Mori](http://en.wikipedia.org/wiki/Mariko_Mori)

techniques to selected related work, and finally, section 7 concludes the paper.

## 2. MULTIMEDIA IN ART MUSEUMS

Multimedia is actively utilized in numerous museums, however, it is mainly in cultural heritage and science museums ([4][5][11][12][27][32]). In these types of museums numerous types of interactive installations including tangible user interfaces (TUI) [14] and augmented reality (AR) [1] have been documented. The focus of the communication in these cases is typically learning experiences within culture, history or natural sciences. Thus the interactive installations themselves may become museum objects in their own right, exhibiting knowledge about certain immaterial subjects. In art museums, however, the artworks themselves typically constitute the main visitor experience. Traditionally, this has only left room for small additional discrete signs, a catalogue, or perhaps an audio guide explaining about the artist, or an explanation of a specific piece of artwork and the inspiration behind it. A main issue for art museums is to avoid disturbing the pure art experience with the communication means chosen.

Experiments on augmenting art museums with interactive technology have been documented. For instance, Terrenghi and Zimmermann [30] introduce the notion of 3D sound in headphones (LISTEN) for an art museum, providing the user with a contextual and spatial audio guide. This technology is an advanced version of more traditional audio guides, and it still provides only an individual experience, since no conversation is possible while listening. This communication approach does not disturb the experience of purely visual artworks; however, it would be difficult to combine with artworks that contain sound by itself.

Another example is the use of projected overlays as illustrated by Bimber et al. [2]. Here the idea is to utilize computer graphics and augmented reality techniques to provide projected overlays on backgrounds with arbitrary colour and reflectance. Thus the pictorial artwork itself constitutes the background for projected explanations or pictures of inspirational sources etc. The assumption is that the pictorial artwork is augmented with a projector similar to a spotlight directed at the artwork. This is highly advanced in its use of real-time computer graphics rendering, and it does provide a shared experience for groups of visitors. However, the approach is problematic as seen from a museum perspective, in particular when the focus is on modern art, because the projections seriously disturb the experience of the original artwork. The high quality projection may partly or fully cover the original picture. We anticipate that most curators and artists will be sceptical towards such an augmentation of the artwork.

## 3. INTERACTIVE SPATIAL MULTIMEDIA FOR ART MUSEUMS

Based on the above examples, we see special challenges for multimedia in art museums. Many museums wish to go beyond the pure individual experience toward shared social experiences that integrates seamlessly with the artwork. To achieve shared social experiences we are inspired by aesthetic interaction [24], which argues for interaction techniques that are socially appealing and that involve more of the human senses in the interaction.

## 3.1 Spatial Multimedia

When designing multimedia installations for physical museum spaces, the objective is not merely on designing multiple content forms, including combinations of images, audio, animation, text, video and interactive elements. The context of what constitutes the multimedia experience needs to be investigated from a holistic and social perspective. Since the emergence of ubiquitous computing, the context of the experienced interaction space has been broadened from a more traditional human-computer relation, to a relation where the human being is also a sensing body situated in a physical space, and where the computer has disappeared - or at least alternated into interior, surfaces or physical elements that we traditionally do not combine with multimedia content. The manner in which communication means are staged in exhibitions, is highly dependant on the physical surroundings, e.g. the size of a room, the atmosphere, or the materials used (for instance some surfaces absorb sound, others reflect it). However, when appropriating a physical museum space as a visitor, space is more than the physical structures that constitutes the surrounding environment. It is also the experienced space of communication, which appears when a visitor encounters an art work through a multimedia installation. In this manner, we understand spatial multimedia in a physical museum context as media that includes a holistic and social perspective on the visitors' experiences.

## 3.2 The Body as an Interaction Device

The idea of emphasizing the use of the body stems from a wish of the museum to avoid computer like interaction and wearing of devices like mobile phones or PDAs. Introducing interactive elements in the physical space should maintain the visitors in a role as active participants who explore knowledge and not just consume it. Further, by using the body as an interaction device, the communication of art makes better use of the human's sensory and motor systems, and enables the user to experience the art through physically and socially engaging activities.

The use of the body as an interaction device has been proposed for museums by Sparacino [28] for an exhibition about Puccini as Set Designer. Here techniques such as Immersive Cinema, Interactive Documentary tables, and Museum Wearables are introduced. These techniques are, however, mainly individual and based on turn taking, where one visitor interact and many observe it. Webb et al. [31] introduce the Choreographic Buttons system, which provides social interaction in a system by utilizing human movement for interaction. Moreover, work on interactive floors ([8][9]) also support social interaction with the body as the only interaction device. Finally, a wide range of techniques ([13][21]) involves the body in interaction to various degrees, an overview can be found in [17]. The body may work either as an implicit interaction device, e.g. a sensor just detects the appearance of the user; or as an explicit interaction device, e.g. sensors/cameras tracks precise movement by the user to select items or invoke actions.

## 3.3 Proposed Spatial Multimedia Techniques

To provide social and multisensory experiences for the art museum domain, we propose three spatial multimedia techniques that were utilized in the project with the ARoS art museum. We will briefly argue for the techniques before we describe how we implemented installations for the actual exhibition based on the techniques. The three spatial multimedia techniques are:

### 1) *Spatially bounded audio*;

Audio communication based on headphones share the problems of depriving the user from being aware of conversations or sounds in the nearby environment, moreover headphone based systems only provide a single user experience. To overcome these disadvantages, we propose spatially bounded audio installations e.g. through the use of sensor controlled directional loudspeakers<sup>2</sup>. Directional loudspeakers have been utilized at art museums, e.g. at the Boston Museum of Fine Arts<sup>3</sup>, however, in this example it was used as a static soundscape. Audio triggered by sensors have been utilized in an art museum context in the Sonitecture [15] installation, however, this does not use directional audio.

Another technique for bounding audio is audio peepholes, where audio is bounded by a listening hole in a wall or similar. Audio peepholes are special cases of the more general peephole metaphor for experience design proposed in ([4][3]).

### 2) *Floor-based multimedia*;

Traditional communication on vertical surfaces such as wall sheets or plain text on the walls of the exhibition, makes the experienced communication space a matter of what is going on between the eyes of the visitors' and the walls. In order to include other parts of the potential communication space, we propose floor-based multimedia, which through its horizontal placement relates to the bodies of the visitors', as they become part of the interface. Furthermore, as opposed to vertical multimedia interfaces where text, pictures and videos are to be seen from one direction, horizontal interfaces can be approached from multiple directions, which challenge the spatial staging of the reception and holistic experience. Finally, interactive floors have the potential of supporting social experiences when they support multi-user interaction.

Interactive floors with movement based interaction have emerged in recent years. They fall in two main categories: sensor-based and vision-based interactive floors. Sensor-based interactive floors are typically utilized in play, dance and performance like set-ups, e.g. Magic Carpet [22], Litefoot [7], and BodyGames [20]. In contrast to the sensor-based floors, the vision based floors support a more fluid and natural interaction on a floor surface. Large vision based interactive floors ([8][9]) have been developed specifically to support social interaction with the body as the only interaction device.

### 3) *Multimedia interior*;

When art museums display multimedia content it is often presented through visible screens, loudspeakers and other media devices. The media is assigned a transparent role in the communication, in the sense that it is not concealed that the content is of the medial world. However, recent years have shown that more interactive elements are build into the physical interior of the communication spaces. A cornucopia of different types of sensors and actuators enables users to interact with multimedia content through physical objects that are not traditionally combined with media. Multimedia interior is utilized in a museum context at the Ars Electronica Center, e.g with Gullivers World and City Puzzle<sup>4</sup>. The documentary table in [28] from the Puccini

<sup>2</sup> [http://en.wikipedia.org/wiki/Sound\\_from\\_ultrasound](http://en.wikipedia.org/wiki/Sound_from_ultrasound)

<sup>3</sup> [http://www.holosonics.com/PR\\_MFA.html](http://www.holosonics.com/PR_MFA.html)

<sup>4</sup> [http://www.aec.at/en/center/current\\_exhibition\\_list.asp?iParentID=13877](http://www.aec.at/en/center/current_exhibition_list.asp?iParentID=13877)

exhibition is another example. More generally, interactive interior is being built for numerous contexts, an example is the LiMe interior built at Philips<sup>5</sup>. Finally, interactive furniture like Squeeze [23] is emerging; Squeeze is a multimedia sack chair with built-in pressure sensors, strain gauges, and a Piezo cable, which support playful interaction with an advanced picture frame.

## 4. APPLYING SPATIAL MULTIMEDIA TO THE MARIKO MORI EXHIBITION

This section discusses how we applied the three spatial multimedia techniques in a specific case. The ARoS museum had set the stage for the development of new interactive communication initiatives for an exhibition with Mariko Mori. The objective was to intensify and expand the experiences of the artworks by means of spatial multimedia communication encouraging the visitor to explore, play and communicate with co-visitors. The means of communication aimed to match the idiom and underlying basis of Mori's art, which is a mixture between eastern spirituality, popular culture, futurism, technology and interaction, added a vast amount of historic references. The exhibition "Mariko Mori – Oneness" is about interrelationships and connections between human beings, and between them and the world.

The target of the communication of Mori's art has been to create new contexts and develop interaction design that increases a holistic experience of art for the viewer who chooses to activate them, and not to make ready-made interpretations of the works. The result has been two interactive initiatives: "The Sound of Art" which is 25 audio spots that gently augments the art works, and "The Contemplation of Art" which consists of three separate contemplation rooms (approx. 2 meters wide and of different lengths) in the museum's special exhibitions foyer. The contemplation rooms contained interactive installations communicating the sources of inspiration behind the exhibited works. The contemplation installations are thereby spatially detached from the art works they refer to, however, with a clear reference to the art works, which makes an affinity between artworks and interactive installations. Thus the "Contemplation of Art" differs from the "Sound of Art" in that the latter to a certain extent is more an integrated part of the art experience. In the following, we describe the spatially bounded audio technique, which was utilized for the "Sound of Art" concept.

### 4.1 Spatially Bounded Audio

The Sound of Art consists of 25 audio spots located in the exhibition next to the art works. Each spot consists of a visual silver circle at the floor, and four meters above the circle a directional speaker and a PIR (passive infra red) sensor which registers when a user is entering the circle. By shielding the PIR sensor in a tube, the area to be sensed could be specified accordingly to the size of the circle on the floor. The user's movement into the spot triggers played back recordings with clips of Mariko Mori's voice gently supplementing the artworks. Only when standing inside a circle is it possible to hear the artist's whispering comments on the artworks. In this manner, the hearing experience is individual and somewhat intimate creating a private

<sup>5</sup> <http://www.design.philips.com/about/design/portfolio/researchprojects/smartconnections/livingmemory/>

audio spatially bounded space. However, there is a visual as well as an audio awareness of the audio spaces even when entering the exhibition room, which to some extent also makes the experience of the communication space a social one. The visitor can see other visitors standing on the circles which first of all make an awareness of the fact that a given content can be explored when standing on a circle. Additionally, being in the same open space as other visitors experiencing the same art works contributes to constant awareness of other visitors. An audio awareness of the audio spaces is also present due to the sound waves from the directional speakers, which are slightly reflected in the floor creating a deadened soundscape.



**Figure 1: A directional speaker above an audio spot marked by a silver circle on the floor. The visitors tend to look for a loudspeaker when they encounter an audio spot for the first time.**

The audio clips are randomly selected and can be heard independently. In case the user makes a small movement, a new audio clip is triggered until all the clips have been played an equally amount of times. Some of the art works are augmented by more than one circle. The silver circles are in three different sizes indicative of the type of material being communicated. Large circles contain overarching thoughts on the works, medium and small circles contain more specialized and specific ideas and considerations. In the design process, the positioning of each silver circle in proportion to other circles on the floor was thoroughly investigated. The circles were not to be placed too close to each other as that could influence the boundaries of the personal spaces of two strangers in a negative manner. On the other hand, the circles should not be scattered too much, as that would result in some of the circles being too far away from the art works.



**Figure 2: The directional speaker and a PIR sensor shielded in a tube four meters above the floor.**

In contrast to traditional audio guides with earplugs or headphones, the directional speakers support the visitors in having shared experiences of the artworks and the supplementary material, in two ways: 1) People standing in the silver circles can still hear what is going on around them, and they may maintain conversation. 2) People (that are acquainted) may share the audio spots by putting their heads together in the listening zone, and experiencing the same audio clips.

The technical design of the audio spots was based on both aesthetical and practical considerations. In principle, it would be possible to utilize build-in pressure sensors in the floor, however, in this particular case, it was preferred to apply PIR sensors to the ceiling in order to avoid wires on the floor. Moreover, we decided to place the recordings for each spot on an MP3 player in order to decrease the amount of computers needed for the communication. However, this choice had the disadvantage that when an audio clip had been activated, it would have to be played to the end, even in the event that the user would leave the circle during the play. Further, utilizing the PIR sensors made the curtailment of not being able to sense whether or not the user is still on the spot after having heard an audio clip. It is the apparent motion that is detected when an infrared source with one temperature, such as a user, passes in front of an infrared source with another temperature, such as the floor. Consequently, the PIR sensor will not trigger a new audio clip unless the user moves. However, preliminary tests revealed that even a slight movement would be sensed by the sensor.

In the following, we will describe another spatially bounded audio technique utilized for the exhibition.

#### *4.1.1 Communicating “Kumano” and “Tom na h-iu”*

In one of the contemplation rooms, called “The Spirit from the Past”, we also applied the spatially bounded audio technique, however, slightly different from the “Sound of Art” concept.

First of all, the spatial staging of this contemplation room differs from the other rooms by not utilizing interactive elements in the communication. When entering the room, the user navigates through a labyrinth of banners with inspirational material behind the work “Kumano” printed on them. The user arrives at three listening posts in the wall where the user can hear and read inspirational material behind “Tom na h-iu” (the content of the text and the audio is identical as it is can be difficult to grasp). In the case of the 25 audio spots the spatially bounded audio is more or less either present or not, as opposed to the audio from the three listening posts that is played continuously, and experienced as if it increases in volume when approaching the wall. Yet, it is necessary to get very close to each post in order to distinguish the different content from the

others. In the design process the sizes of the holes were considered carefully. The holes should invite the visitors to explore the content and should not reveal itself too much in the other end of the room. On the other hand, the sizes of the holes should make it possible even for senior citizens to read the text at the wall sheet.

The atmosphere in the room is influenced by a forest ambience sound and changing light, making the room more evocative than the other contemplation rooms, which some visitors found to be a nice variety. Further, this contemplation room differs from the other rooms by being more appealing to guests to whom textual communication is the preferred means of communicating art.



(a) Building the three listening posts. Loudspeakers, lights and a wall sheet with text are installed in each box behind the holes.



(b) The banners and listening posts (Photo: Ole Hein).

Figure 3: Communicating “Kumano” and “Tom na h-iu”.

## 4.2 Floor-based Multimedia

In the following, we describe the second spatial multimedia technique “floor-based multimedia” which was applied on some of the installations in the contemplation rooms.

In pursue of involving a larger part of the potential communication space, including the bodies of the visitors, we have developed two interactive installations that enables floor-based multimedia: a vision-based and a sensor-based interactive floor.

### 4.2.1 Communicating “Esoteric Cosmos”

One of the contemplation rooms was dedicated to communicate inspirational material behind the artwork “Esoteric Cosmos”. The art work consists of four 6 meter long photographic collages inspired by the four elements wind, fire, water and earth. This installation has clear references to the “Esoteric Cosmos” art piece in that it exposes four visual areas. Each of the visual areas provides inspirational material related to each of the four elements that have inspired the original artwork.

The interactive installation uses camera tracking from the ceiling to detect when users approach a silver circle projected on the floor. Inside the silver circle four circles are displayed representing the four elements. When the user stands in front of one of the circles his or her silhouette is used as input (using camera tracking) and a sound starts to play inspired by the element selected. The sounds are played from loud speakers located at the corners of the room accordingly to the sequence of the visual elements. Furthermore, an image of one of the inspirations behind Esoteric Cosmos is displayed. After a few seconds the image fades away and background information about the inspiration appears as text. A few seconds later the element goes back to its starting point and can yet again be activated.

In the design process it was considered among other things to include coloured lighting and animations to substantiate the characteristics of the four elements, however, the museum wanted to keep it simple and pure in line with the idiom of the artist.

Vision-based interactive floors are dependent on the light conditions of the room, and the system is calibrated accordingly to the surrounding environment. There should be enough light to create silhouettes on the white floor when the users interact with the installation. In case the lighting is not sufficient, the dark areas of the projected interface could be tracked as input. On the other hand, too much light will overexpose the users’ silhouettes and complicate the tracking. Additionally, if there is too much light, the users will not be able to see the projected interface. Thus, the ideal set-up for a vision-based floor would be in a controlled environment. Camera tracking was chosen in order to utilize different interaction techniques, which was a wish from the museum, and the room seemed to be a controlled environment having placed the doorway in one side of the room and the installation in the other. However, concurrently with the changing seasons, direct sunlight occasionally interfered, causing the installation not to work intentionally, which could confuse the visitors. However, most of the time, the tracking was robust.

### 4.2.2 Communicating “Oneness”

The other interactive floor installation (shown in Figure 5) is sensor-based, and is meant to communicate inspirational material for the piece “Oneness” which is six green aliens standing in a circle holding hands. When all six aliens are hugged at the same

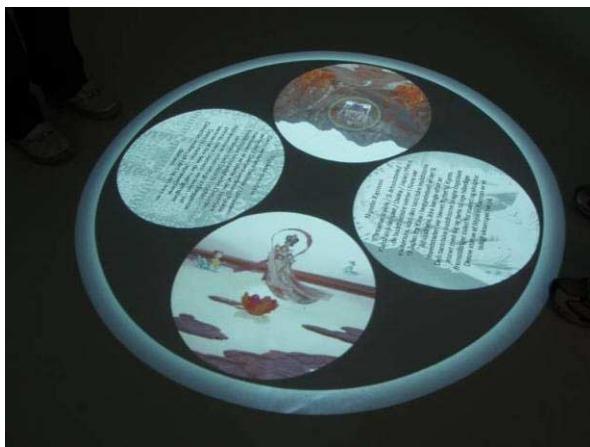


time by the audience, the floor lights up and the users can feel the heartbeats of the aliens creating a feeling of oneness.

The Oneness installation refers to the art work in that the number “six” and pictures of aliens recur in the installation. The installation is a floor with six built-in pressure sensors placed in a circle around a projection of inspirational material. The pressure sensors providing the interaction opportunity are visually indicated by six silver circles and a projection of an alien in the middle. When a user stands on one of the pressure sensors, the alien disappears and one sixth of an inspirational picture behind Oneness is displayed. Three different pictures can be selected depending on which sensor is first activated. Further, six different sounds indicate each time someone steps on a silver circle and the sound intensity increases accordingly with the amount of activated circles. In the rim of the circular display a text is revealed with the inspirational picture. When the entire image and text have been revealed, the sound develops after a short period of time and an animation of another one of Mariko Mori’s aliens appears. In this manner, the users have to communicate and work together in order to find out what happens when all six pieces of a picture are revealed. This makes the installation socially engaging and especially children have found it interesting to explore the installation. Observations have shown that the sounds contributed substantially to the experience, and that this installation constantly attracted other visitors that would have a look from the doorway.



(a) A projector and a computer are hidden in the ceiling. A webcam tracks the users’ movements and four loudspeakers play sounds of the four elements.

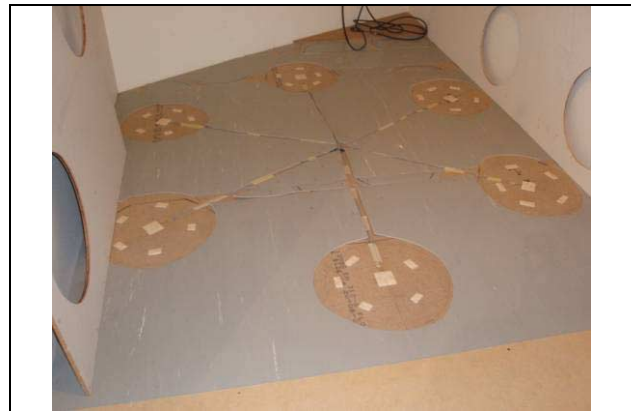


(b) Communicating “Esoteric Cosmos”: four elements represented as camera tracked spots in a silver circle.

Figure 4: Communicating “Esoteric Cosmos”.

In the design process it was discussed how the floor should be constructed. The initial idea was to have the interface projected at a raised platform. However, due to the limited space of the room, the interface and the silver circles were put in the same level at a small podium that could conceal the junction of the pressure sensors. In this manner, the installation could stage the space of the communication.

In contrast to the Esoteric Cosmos installation, the Oneness installation has fixed places where the visitors have to stand in order to interact with the installation. This element of fixation corresponds to the Oneness art work, where the users hug the aliens from six fixed spots, and thus making the choice of interaction technique for the installation suitable. Further, the robustness of the pressure sensors proved to be impeccable.



(a) Six build-in pressure sensors in a podium. Vinyl makes the right cushioning for the sensors to register the users.



(b) Communicating “Oneness”: All pieces of the picture are revealed when all six silver circles are activated.

Figure 5: Communicating “Oneness”.

The third spatial multimedia technique “multimedia interior”, which was applied on the communication of the art work “Wave UFO”, will be described in the following.

### 4.3 Multimedia Interior

Utilizing multimedia interior at exhibitions can be a challenge as the interior should be robust and secured. The assumed relations with the interior should be considered carefully to prevent personal injury of any kind. For this exhibition we designed a staircase for bodily scrolling, which will be described in the following.

### 4.3.1 Communicating “Wave UFO”

The installation communicating the “Wave UFO” art work (shown in Figure 6) enables the visitors to explore inspirational material behind the piece, which is a stunning sculptural object in which three people at a time can explore the relationship between the individual and being interconnected, through real-time computer graphics and brainwave sensing technology.

The UFO installation is a staircase with built-in pressure sensors located underneath a 42” screen displaying inspirational material behind the artwork. The staircase is a direct reference to the UFO artwork which contains a ladder. The user can scroll the material by climbing up or down the stairs. Each part of the staircase (left, middle, right) displays material from three different categories: sketches from the building process of the UFO, brainwaves and patterns displayed inside the UFO, and architectural drawings and 3D models. When multiple users stand on the staircase at the same time, the screen is split in two or three “tracks” allowing multiple images from two or three different types of background material to be displayed at the same time. The staircase has nine stair treads, each with a pressure sensor under the tread. The visual feedback is accompanied by a rumbling sound from a subwoofer in the staircase each time a user takes a step up or down.



(a) The staircase used for the UFO-installation. Nine holes ensure inputs from nine pressure sensors.



(b) Communicating “Wave UFO” inspirational material: climbing a staircase to look into the UFO.

Figure 6: Communicating “Wave UFO”.

Initially, the subwoofer was not a part of the design. However, we experienced the need for audio and tactile feedback to supplement the visual feedback, as the attention of the visitors’ was often on the staircase itself when placing a foot on a new stair tread. Thus, it was necessary to clarify the connection between the users’ movements and the outcome. Thus, the integration of the subwoofer was a success, and it added more playfulness to the installation.

Further, the nine treads were not initiatively equipped with nine silver circles, which made it very difficult to comprehend that there were nine treads and not three. The staircase should initially have been three separate staircases. However, for spatial and technical reasons, one staircase was made, containing the computer, subwoofer and the cables to the sensors.

The staircase was constructed very robustly so it would not slide when mounted. We deliberately did not apply a banister to the staircase, because we found that it would have a great influence on which stair treads would be used the most by the visitors. However, this choice had consequences on the way especially senior citizens acted on the staircase, as they were very careful, and not many seniors made it past the first stair tread.

Additionally, the limited space in the room made it necessary to place the staircase relatively close to the screen. This made it difficult to obtain sufficient distance to the screen, which meant that the three top treads were mostly used by children.

With the staircase, the visitors could have a chance to see some of the images depicted in the Wave UFO art work, which not all of the visitors have had a chance to experience. However, some visitors found the way of interacting a bit too artistic. Not all the visitors could tell the difference between art works and communication installations.

## 5. LESSONS LEARNED

The project has been evaluated quantitatively through questionnaires and qualitatively through interviews. The aim of the evaluation has been to examine the users’ experiences of the art communication. This evaluation has been documented in [16]. Here we summarize some of the results and briefly discuss lessons learned in relation to the spatial multimedia techniques’ target group and the ability to support a holistic experience.

The questionnaires were over a three day period handed to 150 visitors, from whom we got 91 filled in questionnaires in return. The questionnaires consisted of 32 multiple-choice questions with openings for freestyle text writing. The age distribution of the respondents were as follows: 0-10 years: 6%, 11-20 years: 21%, 21-30 years: 9%, 31-40 years: 15%, 41-50: 25%, 51-60: 13%, 61-70 years: 11% and 70+ years: 1%.

The interviews were conducted with four groups of 2-3 visitors representing different segments. The interviews were semi-structured, starting with more factual questions and following a “guided tour” in the sense that the interviewees were encouraged to tell about their experiences, where they went, and what they did, based on a floor plan. Furthermore, the interviewees could put green stickers on the floor plan if their impressions of a particular place or installation were predominately positive, and red stickers if they had had a negative impression. The interviews lasted approximately 30 minutes and were recorded on a Dictaphone.

In general, we found that the three techniques seemed to work in order to communicate information about the artworks, and they worked with respect to engaging the visitors in active exploration using their bodies. They also worked in conveying the interaction techniques to the visitors without further explanation.

It is particularly remarkable to see that they appeal to the entire range of age groups and not just to youngsters or children. The issues of target groups for multimedia in museums have been addressed by numerous researchers in that they have focused on the role of interactive technologies for children experiences within the museums ([9][10][11][27]). The evaluation [16] of the Mori exhibition showed that young people found the spatial multimedia installations engaging in a degree that it would encourage them to visit art museums more frequently. However, our evaluation actually showed that this was also true for most other age groups. Only the oldest age group in our analysis was too small to make conclusions about. 66.7% of all of the respondents answered that they would be more likely to visit future art exhibitions if they were augmented by interactive installations. Thus, we believe that spatial multimedia will address a broad target group. Moreover, our installations also supported shared playful experiences within families across ages.

The interviews showed that the success of the spatially bounded audio installations depended on where the installations were located in the exhibition area. E.g. the audio spots located in passage areas were less likely to be explored by the users than the ones that were located in areas that would afford immersion and serenity.

The spatially bounded audio made the communication an integral part of the art experience. By choosing Mori's voice instead of a distanced narrator's voice a notion of integration was enhanced. This fact made most visitors think that the audio was part of the art works. 7 out of the 10 interviewees made statements that implied that they thought the audio was an integrated part of the artworks.

As regarding the contemplation rooms, it became evident - especially in the interviews - that even separate rooms with the words "Non art zones" printed on the wall could be mistakenly assumed as being art. This could be due to the fact that the communication as well as the art utilizes technology and interaction.

Among the means to achieve a coherent holistic experience connecting the artworks and the remote contemplation room installations are the clear reference between the art works and the communication of the art works. This reference is referred to in [16] as "conceptual affinity", and it seemed to work since our evaluation showed that many users were not able to tell the difference between art works and the communication of the art works when leaving the museum, and believed all of the installations were made by the artist rather than the curator and the design team.

Whereas some visitors (including one of the interviewed groups) found it disappointing to learn, that some of what they thought was art, was merely art communication; another interviewed group thought it was a success when it was not possible to tell the difference between art and art communication. Thus we have indeed succeeded in creating a holistic experience at the exhibition, the distinction between art works and art communication has gotten blurred.

As seen from the point of view of an art critic, it may be problematic that we have blurred the borders between the art per se and the communication of the art. It is, however, important to notice that the interactive installations have been developed in concordance with both the artist and the curator on the exhibition. The only adjustment of the installations that has been made in order to not compromise the artwork is that we had to remove a specific background sound from the installation communicating "Esoteric Cosmos". This removal was requested by the artist. However, neither the artist nor the curator find the blurring problematic, in fact they consider the holistic experience a quality of the exhibition.

## 6. RELATED WORK

We briefly compare our three spatial multimedia techniques to previous work with similarities to these techniques. Finally, we discuss our work in relation to other researchers' experiences with target groups for multimedia in museums.

### 6.1 Spatially Bounded Audio

Terrenghi and Zimmermann [30] introduce the notion of spatial 3D sound in their communication in art museums. However, it is not spatial multimedia in the same sense as we propose, since it relies on headphones, and thus deprives the visitors from conversation and shared experiences by listening to the same audio clips. Thus we claim that our spatially bounded audio technique can provide both personalized experiences similar to the ideas of Eisenberg et al. [5] as well as shared experiences.

Spatially bounded audio by means of directional loudspeakers has also been used at the Boston Museum of Fine Arts<sup>6</sup>. In this case it was utilized to create a spatially bounded soundscape in a certain area of the museum. In contrast, we have distributed directional loudspeakers to all the artworks and have used sensors to trigger various sequences of speech when visitors move into the loudspeaker zones. This varies the experiences, since it will take quite a long time before the same pattern is repeated.

### 6.2 Floor-Based Multimedia

The use of floor-based multimedia in terms of Immersive Cinema has been proposed for museums by Sparacino [28]. Our experiences support that this is a promising technique for the museum domain. We have argued to go beyond the Immersive Cinema which is a single user experience, by supporting multiple users and social interaction on the floor. This has proven to be successful in the Mori exhibition, where both young and old people were encouraged to explore material and communicate with each others. The techniques we have utilized are in line with the vision-based interactive floors: iFloor [18] and iGameFloor [8][9]. These interactive floors stick to interaction in the 2D space. Webb et al. [31] also support social interaction in their Choreographic Buttons system and they utilize vision-based techniques to support some aspects of interaction in the third dimension, by being able to track jumping and crushing.

### 6.3 Multimedia Interior

The Interactive Documentary tables by Sparacino [28], Gullivers World/City Puzzle<sup>7</sup> from Ars Electronica, and the AR tables by

<sup>6</sup> [http://www.holosonics.com/PR\\_MFA.html](http://www.holosonics.com/PR_MFA.html)

<sup>7</sup> [http://www.aec.at/en/center/current\\_exhibition\\_list.asp?iParentID=13877](http://www.aec.at/en/center/current_exhibition_list.asp?iParentID=13877)



Woods et al. [32] are all examples of spatial multimedia interior produced for the museum domain. These pieces of interior are all made for explicit workbench like interaction with multimedia material. In contrast, we have been experimenting with interior that support a more implicit interaction with some randomness. Our staircase with sensors triggers random starting points and splitting points in the multimedia material and it scrolls the material back and forth depending of visitor movement on the stairs. This encourages a playful behavior, and we see much more potential in developing this kind of playful interaction to inspire and encourage exploration at museums. The randomness and serendipity supported by this interaction can be further inspired by interactive furniture like Squeeze [23] which supports playful interaction with family photos in a large picture display.

## 7. CONCLUSIONS AND FUTURE WORK

This paper has discussed the application of three spatial multimedia techniques for communication of art in the physical museum space. The case was a Mario Mori exhibition at the ARoS museum in Denmark. We developed a number of spatial multimedia installations where the only interaction device being utilized was the human body. Combined with the art work, these installations supported visitors in holistic and social experiences with seamless transitions between art experience and communication related to the artworks. The three techniques were: 1) spatially bounded audio; 2) floor-based multimedia and 3) multimedia interior.

The applications of these techniques for communication of information in the specific Mariko Mori case have been described, and so have the spatial multimedia installations and their implementation. The multimedia installations were in function for a three and a half month exhibition period and they were approved on beforehand by the artist to be in concordance with the artworks.

We hope in near future to get the opportunity to try out the spatial multimedia techniques for more traditional exhibitions at the ARoS art museum, where they are planning to revitalize their classical art collection with new means of communication. In such a classical exhibition, the form of artwork expression will be less close to the form of communication provided by spatial multimedia. This will challenge the techniques in order to achieve similar seamless transitions between artwork experiences and art communication experiences.

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