http://dx.doi.org/10.14236/ewic/eva2015.28

# meSch – Tools for Interactive Exhibitions

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**Digital media offers great possibilities to present cultural heritage: visitors can interactively explore content and the content can be dynamically presented according to the situation in the exhibition. For instance, little content may be presented in larger letters if the visitor is standing far away from the exhibit, but if the visitor is coming closer, a larger body of content can be presented using smaller font sizes. One major goal of the meSch project is the development and integration of interactive technology into museum installations that senses visitors' actions in an exhibition and presents digital content according to the visitors' actions, such as position, visit trajectory, language preference, age or interest. We aim not only to empower curators and cultural heritage professionals but also interaction designers to design digital museum experiences and to build interactive exhibitions. Thus, we present here the meSch platform that enables to easily setup interactions in exhibitions. We present the general meSch concept, highlight the Plinth, a prototype that allows measuring the distance of visitors to an exhibit, and describe how the Plinth can enrich exhibitions as interactive component. Finally, we elaborate the iterative design process of the Plinth including an evaluation in an interactive exhibition as well as a re-design based on the results of this evaluation.**

*Interactive exhibition. Proxemics interaction. Architectural guidance.*

## 1. MESCH PLATFORM – A TOOL FOR BUILDING INTERACTIVE EXHIBITIONS

With the meSch platform we aim to support curators to design interactive exhibitions by themselves (Petrelli et al. 2013). Cultural institutions often neither have the budget to have employees with technical expert knowledge to design and build interactive exhibitions nor the financial resources to outsource them. Moreover, cultural heritage professionals have their background mostly in history or art, and often they gained additional technical knowledge allowing them to edit webpages or content managements systems.

Thus, cultural heritage professionals most likely are able to edit digital tools, but they will probably rather seldom have the skills required to develop interactive exhibitions from scratch. Moreover, curators still want to have control over their exhibitions and taking extra care of them. Introducing tools and platform that is easy to use enables them to setup and create the interactive exhibitions themselves and prevents the need of involvement of external technicians.

To provide a system that allows cultural heritage professionals to setup interactive exhibition the meSch platform – a hardware configuration tool based on an easy programming approach – has been developed (Kubitza and Schmidt 2014). The meSch platform is a centralized approach that allows an easy mesh up of hardware components by non-technical users through a web based user interface to sense visitors' actions in an exhibition and to provide digital content accordingly that can be defined by curators using the meSch authoring tool. The authoring tool is an extension build upon the meSch up platform that allows the generation of interactive scenarios and personalizing the content.

The meSch platform supports the currently most established DIY hardware systems: Arduino, Gadgeteer (Villar et al. 2012), and RasberryPi as these systems have been especially designed to allow non-technical skilled people to build interactive prototypes. Moreover, these systems are comparably cheap and much support of the DIY community in using these systems is given. Thus, if a curator may need help in setting up hardware components, she/he could post questions in dedicated forums and would most probably rapidly get answers, while no service fees would be charged.


***Figure 1:*** *Plinth prototype designed in a participatory design workshop with cultural heritage professionals that senses visitors around an exhibit and projects content according their position*

To demonstrate possible applications of the meSch platform several prototypes have been developed, e.g.:

- a Book-like device named the Companion Novel (Hornecker et al. 2014). The book consists of sensors and actuators. This allows the visitors to have personalized information based on placing bookmarker in the book.
- an RFID tag that allows to identify a user reading out an ID from his/her ticket that may be embedded in a wristband to allow for identifying the visitor when he/she is touching an RFID reader embedded in an exhibit,
- an interactive Plinth that measures the distance between a visitor and an exhibit placed on top of the plinth (see Figure 1), and
- a Projector Lamp that displays interactive content that could be controlled using the RFID reader or the Plinth as input device. For example, if the Projector Lamp would hang above the Plinth it could display according to the visitors distance, which refers to the notion of proxemics interaction that will be described in more detail below. For example, the font size of labels could decrease when the visitor approaches the Plinth. If the Projector Lamp would use the RFID reader as input, information in the preferred language of the visitor could be displayed. That would only require that the language preference is recorded when selling the exhibition ticket and then saved with the ID of the RFID that is embedded in the entry ticket.

The prototypes described above have been developed in a co-design workshop with cultural heritage professionals and interface developers (McDermott et al. 2014). To test the concept and to evaluate the technical configuration chosen we need to implement the prototypes namely the interactive Plinth in an exhibition. In the following sections we describe how we implemented the interactive Plinth in an exhibition, how we analysed the prototype, and how we applied our lessons learnt in a re-design of the interactive Plinth.

## 2. PLINTH – ALLOWING PROXEMICS INTERACTION IN EXHIBITIONS

The Plinth prototype is measuring distances, and here we will discuss the potential of using distances as interaction space.

In 1966, Edward T. Hall studied personal spaces, introducing the term proxemics, a research field to be further explored by scientists and exploited by designers (Hall, 1966). Founding proxemics as a theory enabled him to develop a deep understanding of the human spatial behavior. In his work, Hall visualized personal spaces as four co-centric bubbles surrounding a person. Each bubble represents the corresponding proxemic zone, where the level of intimacy varies. Hall presented his idea as a multi-dimensional problem, where one needs to look from different perspectives to understand and to formulate governing rules that dictate the proxemic distance of a person. One of his very fruitful contributions was establishing a logical relation between languages, experiences and cultures in a dynamic world. He highlighted the major rule of the cultural background and exemplified this difference. He showed how Germans differ from Americans in their comprehension of spaces.

Ballendat et al. introduced Proxemic Interaction (Ballendat et al. 2010), as devices being able to make use of a very detailed set of information about the surrounding environment. This information includes position, identity, movement and orientation of nearby people and devices. Their research was extended by Greenberg et al. to cover five dimensions for proxemic interactions (Marquardt & Greenberg 2012). The five dimensions are: distance, orientation, movement, identity and location. These five dimensions expand the solution space to cover digital devices and non-digital objects, including inputs and states to control the proxemic information of a given device in an integrated ecology.

The Plinth has six proxemic sensors embedded that allow for providing the base for proxemics interaction: information about the distance between exhibition visitors and an exhibit. In an interactive exhibition such proxemic sensor would serve as input device, and we can think of several possibilities of output presentation according to the proxemics of visitors:

- As shown in Figure 1, the labels for exhibits could be interactive, and as soon a visitor is getting closer to an exhibit the labels show more detailed information, display information in different languages or the font size may decrease.
- Moreover, the distance that a visitor should keep to an art piece, which is nowadays communicated via physical barriers or lines drawn on the floor, could be shown through lines projected on the floor. An interactive setup would then allow for dynamically change the distance of the barrier lines. For instance when just few visitors are in the room, the barrier is drawn close to an exhibit, but if many visitors are there the distance chosen is larger to allow more people to see the exhibit at the same time.

Light projections can affect proxemic interaction between exhibits and visitors, in a museum environment. Previous studies attempted to investigate the effect of ambient lighting conditions on human spatial behavior. Adams and Zukerman (1991) studied the effect of bright and dim illumination conditions on personal space requirements. However, they did not consider a particular lighting setting, that is, they considered ambient light with brightness as a variable. Also, in their study, they considered person-to-person interactions, which did not incorporate any exhibits.

In this paper, we investigate how we can measure the distance between visitors and an exhibit to allow for proxemics interaction. Such interaction could be floor projections affected by proxemic interactions between visitors and exhibits. To allow for proxemics interaction in exhibitions, we implemented the Plinth that has been developed in a co-design workshop in a real exhibition. We were evaluating the dada measured with the Plinth by using a surveillance 180° fisheye camera in addition to have external validation of the Plinth measurements. That will allow us to identify limitations of the first Plinth prototype and to develop a more advanced version.

## 3. AN EXHIBITION AS EVALUATION ENVIRONMENT

The Plinth prototype is supposed to demonstrate one possible interaction within the exhibition context among others, like the RFID reader or the projector lamp. As described above, we developed the interaction concept as well as the first prototype in a co-design ideation workshop. The feedback of the cultural heritage professionals (that were involved in the design process) about the created interaction ideas and prototypes was very positive. However, we are aware that the designers' opinions are biased and thus, we need external validation about the Plinth design and prototype. Most likely the first Plinth prototype needs more design iterations to fulfil the requirements of an interactive exhibition interface, e.g. running stable over the duration of an exhibition. Thus, we apply the design thinking method (Brown 2008) through evaluating early prototype stages to understand their limitations, then refining the interaction and interface design, and again evaluating the next prototype generation.

While user studies in the lab have the benefit to fully control the experiment procedure, we decided to implement the Plinth in a real exhibition space to be faced with circumstances and challenges of a realistic exhibition situation. While we first tried to integrate the Plinth in a concept of an exhibition planned by the Akademie Schloß Solitude, we learnt that artists and curators unlikely are willing to compromise their exhibition design according the needs an evaluation. Thus, we decided to design and curate an entire exhibition by ourselves, and we luckily got the entire gallery space of the Akademie Schloß Solitude for four weeks to implement the Plinth and to run an exhibition called "art meets science" by ourselves for one weekend

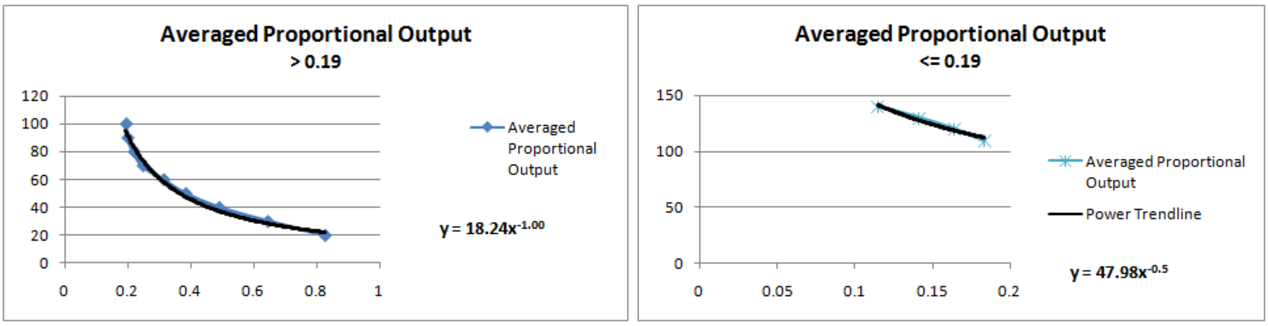


***Figure 2:*** *Distances between the IR sensor and a person or object plotted against normalized proportional sensor output for inputs less or equal (left) and greater (right) than 0.19 normal value*

(Art meets Science 2014). We invited media artists and scientists working with new media and computer graphics to exhibit their work in the “art meets science” exhibition. One work, a 3D printed illuminated human brain called “Geh Hirn in Frieden” was chosen to be presented solo in a room on top of the Plinth to measure the distance in which the visitors approach the exhibit depending on projected lines on the floor in front of each side of the six sides of the Plinth.

## 4. PLINTH IMPLEMENTATION AND SETUP WITHIN THE EXHIBITION

The Plinth embeds six Infrared distance measuring sensors that generate as output a value between 0.4V and 2.6V, each depending on the distance of an object to the sensor. According to the datasheet provided by the manufacturer, the sensor (SHARP GP2Y0A02YK0F) measures distances from 20 cm up to 150 cm. luckily the sensor is not affected by environmental temperature or the operating duration. However, the output voltage, which correlates to the distance between the sensor and the detected objects, is – even after been normalized – not linear (see Figure 2).

To solve this issue, we were calculating a proxemics function that allows us to calculate distances. Using trend line analysis, we could obtain a power function whose output is associated with the actual sensor voltage output values to a high degree. Under the same luminosity conditions, we performed tests in order to collect per distance data that could help us calculate the trend lines. Starting at ten centimeters, distances are collected using one sensor. At each distance, ten values are calculated and then averaged by ten, in order to make sure that the collected results are noise free as much as possible. A colorful piece of cloth was used in this test as an obstacle to be detected by the IR sensors. The sensor provides its output in two forms (see Figure 2). For accuracy reasons, we obtained two different power trend lines for the sensor voltage output, in order to precisely depict our distance values. We can then switch between any of these two functions using conditional statements in the server processing side as shown the algorithm below:

Input: sensor_reading, the normalized proportional output value from the sensor.

```
IF sensor_reading > 0.19 THEN
    proxemic_distance = 18.24 * (sensor_reading^-1);
ELSE
    IF sensor_reading <= 0.19 AND sensor_reading > 0.1 THEN
        proxemic_distance = 47.98 * (sensor_reading^-0.5);
    ELSE
        proxemic_distance = 150;
    ENDIF
ENDIF
```

Now, the plinth is capable to collect proxemics data of nearby visitors. Simply by employing the functions provided above, we could calculate the distance between the Plinth and visitors accurately in a pseudo 360 degree egocentric perspective seen from the exhibit. From a performance perspective, we compared the running time of the power function calculations in Javascript with other equivalent traditional multiplication. Performances were similar, with no significant differences. As each of the six sensors used covers 15 degrees we assumed to have blind spots of 45 degrees every 15 degrees within the 360 degree Plinth tracking spectrum. Obviously the coverage of 360 degrees was not paid a major attention on during the co-design workshop. To compensate for the limitation of the Plinth having six 45 degrees wide blind sports, we chose a floor projection design of a hexagon assuming the visitors may approach the exhibit towards the centre of the hexagon’s edges, see Figure 3.

***Figure 3:*** *Exhibition room with art piece (illuminated 3D brain) placed on the Plinth*

To have external validation in the evaluation of the Plinth, we installed a second sensor, a 180 degree wide angle surveillance camera, on the ceiling above the Plinth. That allowed us to capture visitors' movements in the exhibition, too.

## 5. THE EXHIBITION PROCEDURE

We advertised the exhibition using the newsletter of the Akademie Schloß Solitude and our institute's newsletter. Moreover, we placed flyers in exhibitions and coffee bars in Stuttgart nearby the exhibition space. Thus, about 200 visitors with different background, artists, students, academic employees, and non-academic employees came to the exhibition opening.

The experiment took part during the opening and during the vinissage of the "art meets science" exhibition. Each participant entered the room at a time. Before the subject entered the exhibition room, they were asked to fill in a consent form. After the subjects came out of the room, they filled in the questionnaire containing the demographics questions. Videos are captured continuously using the fisheye camera. Also, the Plinth was continuously running and monitoring the participant inside the exhibition room as he/she wanders around. The visitors that were participating in our study were compensated with a drink voucher that they could use at the exhibition's bar.

## 6. EVALUATION

We collected data by two sources, from which we could obtain our results:

- Fisheye camera videos.
- Plinth proxemic data.

### Fisheye camera videos

For the Fisheye camera videos, the brightness level was very low and the room was dim for the camera to have a capturing quality that is ready to be directly analyzed. Also, the noise level in the captured clips was high. In order to detect and track the visitors we used OpenCV library (http://opencv.org) for image processing and feature extraction. For each captured frame from the ceil-mounted fish eye camera pre-processing phase is essential in order to accurately detect visitors. This phase included noise filtering, background modelling and subtraction, and thresholding. These steps are further explained below.

*Image Pre-processing*
Median Blur flter: since our videos contained a high level of noise, we used a median filter to get rid of it. Using this filter, we were able to get rid of the salt-and-pepper type of noise. By employing a kernel of size 31*31, we could get rid of the noise. This step was important, since the presence of any noise in our images sequence will definitely affect our visitor detection algorithm, particularly if its pixel density is high, as in case of salt-and-pepper noise.

Binary Threshold: after the previous operation, minimum amount of pixels are still affected by noise. By applying a very low binary threshold to the images sequence, we could get rid of this random noise. Using a threshold of 2, we finally obtained noise free videos that are ready to be analysed.

*Background Subtraction*
We used a background subtraction algorithm namely the Gaussian Mixture-based Background/Foreground Segmentation Algorithm. The reason behind choosing this background extraction algorithm is the fact that it has a learning parameter referred to as alpha (α). This allows the dynamic update of the computed background

model which is essential to detect visitors. The alpha values could vary from zero to one. The higher the alpha is, the higher the sensitivity of the background model to changes in the image sequences. Since we applied the algorithm to a sequence of images representing our captured videos, we had to control this alpha. That is, how long the algorithm tries to remember previous images as if they were already processed. In other words, it is a parameter that controls the memory of the algorithm. If set to a high value (less than or equal to one), then the algorithm will always forget the pixel information of an image as soon as it is processed, and vice versa.

Due to the low quality of the image, the fairly static environment and the visitor wandering directions and speed, we used a very low learning factor of 0.009 in order to make sure that the algorithm remembers previous image sequences and considers them in the constricted contour.

*Visitors detection*
At this point we extracted the foreground from the captured image sequence, which is in our case the visitor in the exhibit room. By applying basic contour detection operation to the visitor is detected easily in the exhibition room (marked with a red line in Figure 4).

**Plinth proxemics data**

For the plinth, six infrared sensors were not sufficient to cover 360 degrees. Given the angle covered by one sensor, fifteen degrees as stated in the datasheet (Sharp 2006), we needed more than six infrared sensors. This fact led to the presence of blind spots in the area covered by the Plinth. Thus, having two ways of collecting our data (Plinth and 180° fisheye surveillance camera) was very helpful and fruitful.


***Figure 4:*** *Visitor is detected with the camera (red border line) well as with the Plinth IR sensor (marked through the green lines)*

We noticed that there is a difference between data collected for the same visitor between the plinth and the fisheye camera analysis. Here, we discuss the reasons for such discrepancies and reliability issues of our experiment.

- Blind spots of the plinth should be detected. So, in case of a reported collision by the video analysis that is not found in the plinth data, the video analysis should be trusted.
- The perspective of the fish-eye camera draws a drifted image of the visitors' position in the room. We had to take care that, if a visitor is standing in an upright position, he/she will be displayed by the camera as a line. This means, if he/she bends towards the plinth enough, he/she would be displayed as a point (his/her head only will show up). Accordingly he/she will not be detected by OpenCV analysis as approaching the plinth.

Luckily, the Plinth can detect such behavior, even if the visitor is at a blind spot, his/her distance to the plinth could be estimated through the following methods:

- Detecting persons or hands captured with the surveillance camera using OpenCV analysis to estimate the distance between the exhibit and the visitor.
- Shadow, of tall visitors, covered the floor projection. This occlusion by the shadow happened because our distribution pattern of the projectors was mainly around the Plinth.

- Filtering abrupt noise in the Plinth data, which did not refer to a person shown in the camera data as that may lead to false


*standing within the Plinth's IR sensor range (that are 6 times 15 degrees)*


***Figure 6:*** *Improved Plinth design using 24 IR sensors to avoid blind spots in sensing proxemics interactions around the Plinth*

## 8. CONCLUSION

After presenting the concept of the meSch platform that enables to easily setup interactions in exhibitions, we highlighted the Plinth, which allows measuring the distance of visitors to an exhibit, elaborate the iterative design process of the Plinth, and describe how the Plinth can enrich exhibitions as interactive component.

The Plinth offers the possibility to measure the distance between exhibits and visitors, which can serve as input for proxemics exhibition interaction design. Using the Plinth could support visitors to interactively explore content and the content can be dynamically presented according to the situation in the exhibition. Thus, with this work we aim to support the integration of interactive technology into museum installations and to empower curators and cultural heritage professionals to design and to build interactive exhibitions.

## 9. ACKNOWLEDGEMENTS

We thank the Akademie Schloß Solitude to host the exhibition “art meets science” and Demian Bern to co-curate this exhibition.

The research leading to these results has received funding from the European Union Seventh Framework Program (FP7, 2007–2013) under grant agreement no. 600851.

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