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THE INTERACTIVE DISPLAY OF THE NAGYHARSÁNY ROMAN VILLA FLOOR MOSAIC AT THE HUNGARIAN NATIONAL MUSEUM

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The luxury villa found near Nagyharsány is an extraordinary archaeological site from the late Roman era in Hungary, and several archeological excavations have been performed there in recent decades (Mráv 2021). The mosaic fragments that have been discovered have presented the archeologists, museum scientists, and digital technology experts with a challenge to create a digital reconstruction of these exceptional finds. The purpose of this paper is to provide a comprehensive overview of the interactive floor projection system created for the museum environment and the graphical elements that evoke the colorful world of the original mosaic floor, and thus the opulence of the villa. The technical aspects of the system and the benefits of this type of display will be discussed. Through the aid of projectors, infrared cameras, and a computer, we aimed to create an exhibition space that would display to the museum visitors a full-size digital reconstruction alongside the mosaic fragments that were recovered. The infrared cameras functioned to track the movement of the visitors in the exhibition space. Based on the motion data gathered by the cameras, the computer displayed the interactive content through the projectors. The goal of the project was to create an innovative exhibition space that was capable of presenting an important piece of heritage in a way that could be thoroughly enjoyed not only by expert viewers but also by everyday museum visitors.

Key words: Roman period, villa, floor mosaic, reconstuiction, interactive exhibition

THE MOSAICS OF THE NAGYHARSÁNY LATE ROMAN LUXURY VILLA

An high-status late Roman villa is hidden under the picturesque landscape of vineyards at the foot of Szársomlyó Hill near Nagyharsány. The Mediterranean beauty and climate of this region attracted the imperial elite of the late Roman Empire, including Valerius Dalmatius, an important member of senatorial rank who built his luxurious villa here. A large, square inner courtyard used as a garden is situated at its center, which included structures, garden facilities, and perhaps a fountain. In the middle of this, there was a stately building with a banquet hall. A colorful mosaic partly comprised of glass tesserae covered the entire floor of this banquet hall, and its choice of subject matter suggested that it was commissioned by a sophisticated and educated individual. Greek mythology, personifications of cities, and popular themes of hunting and animal fights provided the content for the figural scenes with their white backgrounds. Instead of the usual semi-circular apsis, the banquet hall terminated in a polygonal shape on its northern side. This apsis had a mosaic floor covering an area of about 35 m^2, which was found in a fragmentary state. Due to this, the position of only fifteen of the 200 pieces could be identified precisely and integrated into a graphical reconstruction. After analysis and documentation, the mosaic fragments were affixed together and lifted out. Many years of restoration work – cleaning, conserving, and identifying related fragments – were required to outline the design of the mosaic and the system of decorative motifs that filled the fields. However, we were thereby able to reconstruct the composition of the mosaic in the apsis that was commissioned by the owner of the villa. There was an elongated octagonal emblem in the middle of the mosaic, which was surrounded by trapezoidal and square fields. Each field depicted a plant sprawling out from a vase with the weaving vines and leaves growing over all the available surfaces. The forms of vases as well as the triangular and

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heart-shaped leaves on the tendrils of the fictitious plant species recurred rhythmically in all of these fields. The ornamentation on the band framing the mosaic running parallel to the apsis wall was also made up of a running vine and the rhythmic waving of tendril spirals growing from it. The surfaces of the mosaic decorated with tendrils are indirect allusions to Dionysus, in whose presence vegetation would start to bloom and grow abundantly. The figurative representation in the central emblem expressed the god's actual presence to the greatest extent. Although only lines of brownish red tesserae indicating the ground survived of this, it is certain that the central scene depicted the figure of Dionysus in one of his most characteristic iconographic representations (e.g. pouring wine from a chalice to a panther and/or leaning on a Satyr). Besides invoking the god himself, imagery of Dionysus represented allegoric depictions of conviviality, hospitality, and the happiness and pleasures of mundane life in the late imperial period.

OVERVIEW OF THE FLOOR PROJECTION SYSTEM

We created a floor projection system to display the mosaic floor, and this was constructed and installed at the Rotunda of the Hungarian National Museum (*Fig. 1*). Placing the display in this part of the building allowed every visitor to experience the interactive exhibit as they arrived. This technology is rare in Hungary, with only a handful of examples of it being used in museums (Mekka Digital, 2014), although it has been used in significant foreign museums with great success (Plane, 2021). According to our knowledge, the life-size floor projection was unique in terms of size (6.92m × 5.56m) among Hungarian museums. Therefore, the system provided visitors with an experience that they most probably could not have obtained at any other local institution. An important benefit of this interactive technology is that it provides information about the exhibited finds more efficiently than static images (Weng, 2017), a fact that is supported by the research of Guaird and Pares (2014). They have shown that the content of a well-presented interactive floor projection increases children's learning. According to research by Basbelle and Halskoy (2010), an interactive exhibit works on more than one level, making visitors contemplate the heritage, establishing conversation between visitors, and inspiring discovery through play.

Hornecker and Stifter (2006) performed research on exhibition spaces at museums, and their results have also confirmed the importance of presenting dynamic content. They highlighted that visitors usually enter in groups and their impressions of a museum are primarily affected by their experience as a group. In this respect, a display using an interactive system such as this presentation of the mosaic floor can be essential. There is no limit in terms of the technology for the number of visitors, so it can be a great social experience to discover the digitally created reconstruction while working together as a group (this effect may be especially pronounced with children).

Fig. 1. The interactive system

THE INTERACTIVE SYSTEM

To create an immersive interactive experience, it was necessary to design a complex system that would be able to track the movements of the visitors in the exhibition space through the use of infrared cameras. The content, which is constantly changing based on the movement of the visitors, is projected on the floor, and thus establishes an interaction and connection between the visitors and the exhibition space.

The first task was to determine the most important parameter of the system, the number of projectors. This parameter had a significant impact on almost every aspect of the setup and the quality of the interactive experience. By increasing the number of the projectors, the overall brightness improves, the content's resolution increases, and the size of the shadows cast by the visitors decreases. On the other hand, a large number of projectors raises a few technical issues that increase overall complexity, the cost of the system, the minimum number of infrared cameras, and the computational requirements. We concluded that the optimal number of projectors would be four. The computer system and the interactive software were able to handle that many projectors reliably and four light sources provide sufficient brightness while keeping the size of shadows acceptably small.

Only a portion of the lights of the Hungarian National Museum's Rotunda can be turned off during the museum's hours of operation, so high intensity projectors were needed. Laser projectors were chosen instead of ones with conventional light sources, because laser devices are better adapted to daily operation of 8 hours for a duration of 3 months. The equipment for the interactive system was mounted on an aluminum truss structure, which had to have precisely calculated dimensions to ensure that the projectors would be mounted at the correct height and with the proper orientation. A factor affecting these dimensions was the mounting height for the projectors, which was determined by the required overlap of the images of the neighboring projectors. The size of this overlap was 15%, which made it possible to combine the images of the four projectors to create a single, seamless image (*edge blend*). Edge blend is essential to create a visual experience where the visitors perceive the mosaic floor as one single image, not noticing the transitions between the images from the different projectors. The design of the system was supported by a laser point cloud, which we used to measure every dimension of the Rotunda.

COMPONENTS OF THE SYSTEM – TECHNICAL INFORMATION

Projector

The resolution of the Panasonic 5,000 lumen laser projectors that were chosen was 1,920 × 1,200, so the edge-blended image contained 3,840 × 2,400 pixels.

The devices have optical zoom, optical lens shift (optically moving the images vertically and horizontally), and digital corner correction. These features proved to be highly useful when setting up the edge blending.

Computer

The interactive system required a high-performance computer that was responsible for performing high intensity real time tasks such as managing the images from the cameras, performing the motion detection based on these images, and creating the interactive content. The most important expectation for the computer was the ability to handle the four displays at the same time. The computer chosen was a Dell XPS 8940 (Intel Core i7 10700, NVIDIA RTX 2070 Super, 32 GB RAM).

Software

There are numerous software solutions available for creating projected interactive floor displays. LuminVision's Advis 2.1 stands out amongst these solutions because it supports the creation of custom effects and has built-in edge blending. The integrated edge blend feature provides considerable benefits because it avoids the need to purchase additional hardware and/or software to create seamless image alignment. The software uses the changes in intensity of the pixels of the camera images to track the movement of the visitors. The advantages of this tracking method are that it is simple, robust, and does not demand intensive computing. Advis has a built-in effect library with highly customizable elements. Due to this, various effects could be created to present the mosaic floor and its digital reconstruction in a unique and interactive manner.

One of the main goals was the creation of a fully automated system, making any operation by museum staff unnecessary. The Advis software was able to send control signals to the projectors so they could be automatically turned on and off at the beginning and at the end of daily operation. A further benefit of the software was that the order of the effects and their projection times could be arranged into sequences.

Camera

The visitors' movements were tracked by cameras that detected the infrared spectrum, so they did not sense the projected images. This characteristic was highly advantageous because the Advis system would therefore not register the changes in the projected content as movement made by visitors.

The infrared light sources were placed next to the optical axes of the cameras. This layout simplified the installation of the devices, but could lead to problems in places where the density of particles in the air is high. This problem is due to the fact that particles close to the sensor cover a large portion of the camera's field and may reflect a great deal of light, resulting in the sensors detecting movement in places where there is no motion caused by visitors.

Aluminum truss mounting structure

The equipment of the interactive system was mounted on an aluminum truss structure. This mounting structure ensured that the projectors were mounted at the correct height and the cameras were positioned and orientated properly. The projectors, cameras, computer, cables, and power supplies were attached to the top of the framework to make sure that they were out of reach of the visitors.

The width of the framework was 8.5 m × 2.92 m, and its height was 5 m. Wooden boards were placed under the aluminum columns to protect the floor of the museum.

Floor

An important part of the projection system was the floor, which was not only the walking surface but also the projection screen. Due to this, we had to choose a uniform white covering with an adequate wear layer to withstand the damage caused by visitor traffic. An additional task was to make the floor surface smoother with the use of tiles under the white surface that compensated for irregularities.

HOW THE SYSTEM WORKS

The exhibition was open daily between 10:00 am and 6:00 pm. The images projected on the floor had to be in operation during this period without interruption. The projectors were turned on and off by the Advis system at the beginning and at the end of the hours of operation. A BIOS setup woke the computer up, and a scheduled task function switched the computer off at the necessary times.

Aligning the edge blend

Setting up the edge blend was a time-consuming process that required gradual attunements to achieve a seamless, high-quality alignment. Performing these adjustments was a difficult task because the physical and optical attunement of the projectors could only be performed 5.2 m above the floor. Our setup sequence required only two operators and there was no need to adjust two projectors at the same time.

The sequence of aligning the edge blend proceeded as follows:

In order to minimize the distortion difference between the images of the projectors, we mounted the devices with an optical axis facing precisely downward. The center of the projected image was coincident with the vertical projection of the projector (in the case of zero lens shift).

Optical zoom

The optical zoom of the four projectors had to be set to the same value.

Adjusting the projectors with lens shift

The projected content could be adjusted vertically and horizontally using the lens shift feature without distorting the image. This process was not digital, but instead optical, and therefore there was no loss in resolution.

Adjusting the projectors with digital corner correction

The images from the projectors could be transformed digitally by individually dragging their corners horizontally or vertically. The use of this function was essential, as experience showed that without it the projected image was trapezoidal even with accurate adjustment, making it impossible to achieve satisfactory edge blend. The use of corner correction resulted in a minimal loss of resolution.

Barrel distortion

When the edge blend was being aligned, the problem of barrel distortion from the projectors arose, which made seamless alignment impossible. The shape of the mosaic allowed us to avoid this problem by optimizing the edge blend on the inner parts of the semicircle of the apsis, so the alignment was satisfactory for the mosaic floor section. Misalignments were still present at the edges, but the projected pixels were black in that area, so the imperfections were not visible.

Effects

Six different visual elements were created through the customization of the Advis effect library. These six elements can be grouped into three classes of effects. Each of these effects were active for 90 seconds.

Reveal effect: The reveal effect had two layers, and the visitors could induce a dynamic transition between these layers through their movement. The top layer was an image of the mosaic fragments that had been discovered on a black background and the bottom layer showed the digital reconstruction together with the discovered fragments. If the Advis system detected motion in the exhibition area, then it would hide the top layer around the visitor and reveal the digital reconstruction together with the mosaic fragments through a subtle transition.

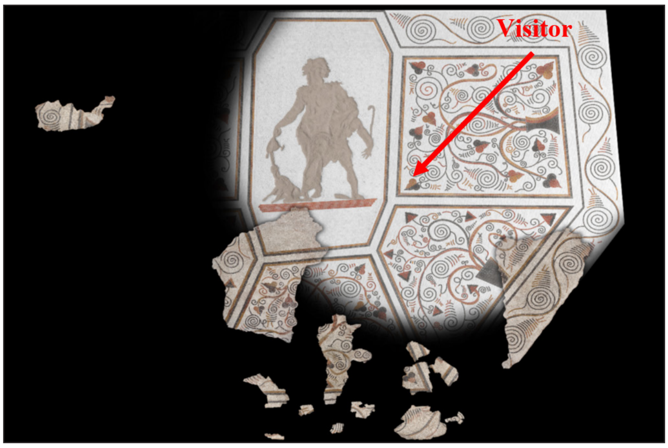

Fig. 2. The reveal effect - the digital reconstruction appeared around the visitors as a result of their motion

Tile flip effect: The tile flip effect had two layers, and the dynamic transition between them was performed through animation. When setting up this effect, it was possible to specify how many tiles the projected image would be divided into. If the system detected motion at any of these tiles, then that area would flip over with a tile-like effect and reveal the bottom layer.

The division of the first tile flip graphical element was 2x2, so when motion was detected, then a quarter of the projected image would flip over and reveal the bottom layer. The top layer was the reconstruction, and the bottom layer contained the discovered fragments and quotations from the Roman era. The tiles flipped back over after 20 seconds.

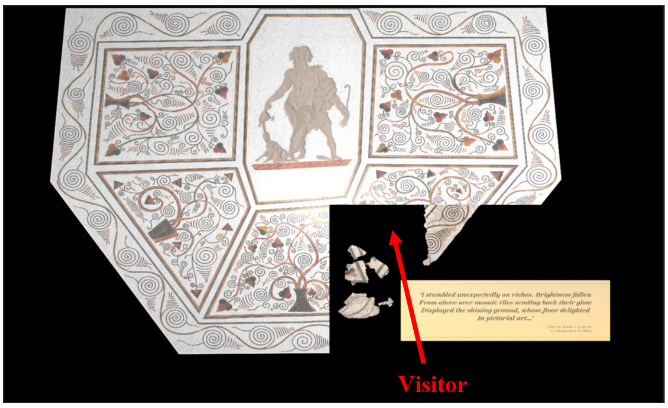

Fig. 3. The tile flip effect – a quarter of the projected image flipped over as a result of the visitor's motion

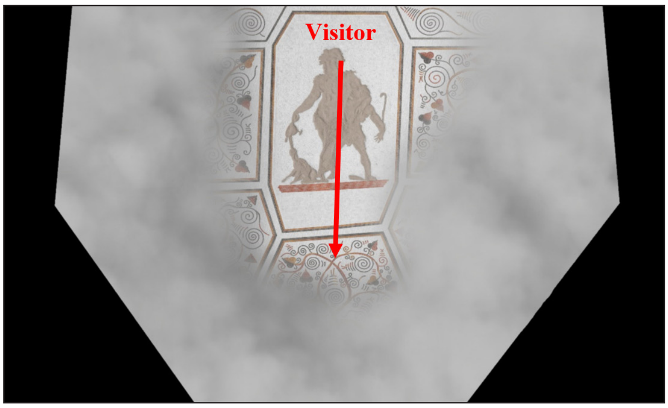

Fig. 4. The mist effect – the mist disappears around the visitor because of their movement

The second tile flip graphical element was divided into 6 rows. The top layer was an image of the mosaic fragments, while the bottom layer was the reconstruction. The rows flipped over and revealed the digital reconstruction as the visitor walked through the area.

Mist effect: This effect had only one layer, a covering of mist animation. Interactivity was achieved using this mist effect, which would disappear around the visitor, revealing the main layer.

Two graphical elements were based on the mist effect. The main layer of the first one was the digital reconstruction without the fragments, with the mist reappearing after 20 seconds.

The image content of the second graphical element was the digital reconstruction and the mosaic fragments together. The mist reappeared after 12 seconds for this graphical element.

OBSERVATIONS AND CONCLUSIONS

We believe that the exhibition that was created served the needs of both the professional audience and everyday museum visitors. We were able to present the mosaic fragments that had been discovered and the digital reconstruction that was created at full size. The transition effects induced by motion made the exhibition more interesting and visually spectacular. In our experience, children enjoyed the floor projection in particular, and they worked either individually or together to discover the entire reconstruction. In our opinion, it was important that the system did not only function as an exhibition space focused on a single individual, but was able to create a memorable group experience.

We are convinced that the potential of floor projection technology is not limited to merely showing mosaic fragments, but it can be used creatively to display various types of heritage in a highly interesting way.

We consider the museum application of the technology justified because it can provide a unique experience that can help stimulate the interest of visitors in the heritage displayed.

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