Enter the Circle: Blending Spherical Displays and Playful Embedded Interaction in Public Spaces

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ABSTRACT
Public displays are used a variety of contexts, from utility driven information displays to playful entertainment displays. Spherical displays offer new opportunities for interaction in public spaces, allowing users to face each other during interaction and explore content from a variety of angles and perspectives. This paper presents a playful installation that places a spherical display at the centre of a playful environment embedded with interactive elements. The installation, called Enter the Circle, involves eight chair-sized boxes filled with interactive lights that can be controlled by touching the spherical display. The boxes are placed in a ring around the display, and passers-by must "enter the circle" to explore and play with the installation. We evaluated this installation in a pedestrianized walkway for three hours over an evening, collecting on-screen logs and video data. This paper presents a novel evaluation of a spherical display in a public space, discusses an experimental design concept that blends displays with embedded interaction, and analyses real world interaction with the installation.

Author Keywords
Spherical Displays; Public Displays; Public Interaction; Digital Interactive Art; In the Wild Evaluation.

ACM Classification Keywords
H.5.m. Information interfaces and presentation (e.g., HCI): Miscellaneous.

INTRODUCTION
Displays in public places assume a wide variety of roles, offering information, interaction, services, and opportunities for cultural exchange. Displays that specifically take on artistic, playful, or entertaining applications can create meaningful experiences that contribute to a vibrant and lively urban living experience. The growing trend to support play, ownership, and communication[1] in public spaces creates new opportunities to evaluate technology and engage with the public through interactive installations. This paper explores how an installation that pairs a spherical public display with embedded interactive boxes can create novel experiences for passers-by in public spaces.

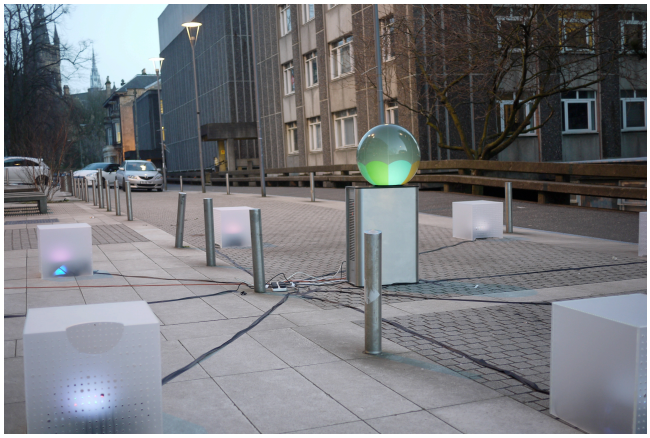

Figure 1. Enter the Circle places a spherical display in the centre of a ring of embedded interactive boxes. Touching the coloured wedges on the display activates the corresponding box around the display.

This paper presents Enter the Circle, an interactive installation that utilises a spherical display and embedded interactive boxes in a playful application. As shown in Figure 1, the installation was staged with a spherical display in the centre surrounded by a ring of chair-sized boxes. Each box is embedded with interactive lights that can be controlled by touching the corresponding wedge on the spherical display. The wedges act as sliders, controlling the brightness of each box individually. Passers-by can interact with the installation and explore its capabilities by "entering the circle" and touching the display. This installation was developed with three key design objectives; to explore staging and the creation of implicit stages, to blend public displays with embedded interactive devices, and to play with control and discovery of control in a performative setting.

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[1] For example, the Playable City Award by Watershed in Bristol, UK. http://www.watershed.co.uk/playablecity/

We evaluated this installation for three hours on a pedestrianized walkway on the University of Glasgow campus. The goal of this evaluation was to reflect on our key design objectives and demonstrate useful design directions for playful interactive installations.

The main contributions of this installation are:

- Novel deployment of a spherical display paired with embedded interactive boxes, blurring the boundary between an interactive display and its environment
- Critical reflection on the design and staging of a playful digital interactive art installation
- Qualitative analysis of real world usage during three hours of deployment without intervention from an experimenter.

PREVIOUS WORK

Playful Public Displays

Public displays are an opportunity for play and exploration in public settings. For example, even displays that are not meant specifically for play are still used playfully in practice. Tomitsch et al. found the users could be more interested in "playing with" a public display than exploring the content provided. They observed that passers-by would dance, gesture, and move frantically in front of the display while playing with their own skeleton that was rendered on screen [13]. Coutrix developed a public display purposefully designed for play and exploration. The FizzyVis system used a ball pit metaphor to engage users playfully with information about a jazz festival [5]. Walter et al. evaluated a playful display in order to understand how different prompts might encourage passers-by the activate features on the display using whole body gestures. In StrikeAPose, if users performed the activation gesture, their shadow would be drawn with a hat or mask [14]. These varied examples of intentional and unintentional play demonstrate how users are often willing to explore an interface playfully even in a public space where they are likely to be observed.

Spherical Displays

Since the first spherical display was presented at SIGGRAPH in 2002 [11], the usability and functionality of these displays has made significant advances. Modern spherical displays support high-resolution graphics, on-sphere multi-touch interaction, and screen sizes varying from 600mm to 2000mm[2].

In the first touch sensitive spherical display, Benko et al. described how multi-touch interactions could be used on a spherical surface [3]. Benko et al. analysed how traditional interaction techniques such as pinch and flick could be implemented on a sphere to manipulate discrete content. They also present new techniques to support collaboration on a sphere. For example, Benko et al. describe the "Send to Dark Side" gesture where users can hold their palm down on content to send it to the opposite side of the display [3].

Bolton et al. explored competitive and collaborative actions on a spherical display [4], developing different software based "peeking" techniques to support collaborative interaction. Their results show that users preferred to walk around the display to see shared content and that conversation over the top of the sphere was widely used, indicating that the physical attributes of the form factor may inherently support these kinds of collaborative actions.

Evaluating Displays in Public Spaces

Evaluating technology outside of the lab in real world public spaces has clear advantages but requires specific metrics and techniques [6]. Alt et al. describe seven key research questions to guide the evaluation of public displays: audience behaviour, user experience, user acceptance, user performance, display effectiveness, privacy, and social impact [1]. These questions can be approached through ethnography and interviewing, lab studies, field studies, and deployment-based research [1].

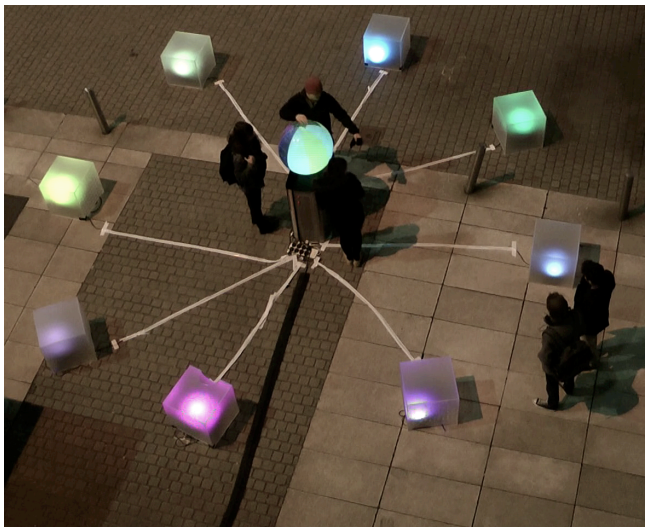

Figure 2. Interacting users stand within the circle while spectators watch from the edges. Users activate wedges and point to boxes as they respond to input.

Some approaches evaluate public display success by looking at the wider space where installations are deployed. Fischer et al. analysed the positions of spectators around a large interactive façade [7]. Fischer et al. describe how the areas around the façade facilitate different types of spectating, such as gap spaces, comfort spaces, and potential interaction spaces. Although these results relate specifically to a large façade interfaces, the analysis approach used by Fischer el al. could generalise to nearly any public display to better understand how people approach, crowd, and spectate around a display. Peltonen et al. completed an intervention study on a public walkway with a touch sensitive

[2] Spherical Displays by Pufferfish Ltd. http://www.pufferfishdisplays.co.uk/

display [12]. Their system, called the CityWall, supported multi-touch interaction with images. The CityWall evaluation used interaction logs and manual coding to evaluate the deployment.

ENTER THE CIRCLE

The Enter the Circle installation involves a spherical display surrounded by eight interactive boxes filled with coloured lights, as shown in Figure 2. The display portrays a coloured wedge for each of the boxes, which can be used as a slider to control the brightness of the lights inside each box individually. In Figure 2, a user controls the lights while pointing to the boxes after realising he is controlling them using the display.

The installation was designed to be a playful walk up experience, exploring staging, interaction with the environment, and discovery of control. The evaluation was staged as a digital art installation with no experimenter present and no intervention after the initial installation. The evaluation was completed on a pedestrianized walkway for three hours over an evening on the University of Glasgow campus.

The key design goals of this installation were:

- To explore staging the display at the centre of an implicit "stage," bounded by a ring of interactive boxes
- To blend purpose built displays with embedded interactive devices
- To play with control and discovery of control in a performative setting

Staging: Creating Actor and Spectator Spaces

Enabling new forms of interaction in public spaces can transform a space into a stage [10], where users become performers and spectators become the audience. When there are specific places for interaction, users can position themselves on and around the implicit stage to take control, communicate their intention to interact, observe interaction and negotiate turn taking.

For Enter the Circle, we aimed to create an implicit stage by building a visible boundary that enclosed the interactive area of the installation. The ring of interactive boxes acted as a boundary to the stage, where users had to "enter the circle" to approach the display and interact. This action involved deliberately approaching the sphere and could be easily observed by others. The boxes could also be used as chairs, which allowed spectators to actually sit and watch others using the display. The spherical display also creates an interesting dynamic in the staging of this installation because there is no front or centre, no "back stage." Users could interact and spectate from many different angles and perspectives, making interactions highly visible.

Blending Embedded and Purpose-Built Interaction

Interactions for public spaces can attempt to blend in with the existing environment in a variety of ways. In contrast, purpose built applications and hardware can also seek to stand out as new elements in the settings where they are deployed. There is a clear distinction between these kinds of installations that leads to different goals, approaches, and outputs. A purpose built public display placed into context is a device that exists solely for the purpose of its own content, services, and interaction. A lamppost that has been embedded with interactive elements still maintains its original functions, but takes on additional roles as an embedded interactive device [8]. Passers-by will have different relationships with a purpose built display than with objects that already exist in their built environment, and this can create new experiences a display alone could not.

In Enter the Circle, the spherical display is our purpose built display and the interactive boxes are our embedded devices. The boxes were designed specifically to be chair sized, matching the height and style of nearby benches. Given the interesting behaviours people exhibit with chairs in public spaces [15], we used chairs as an inspiration for the embedded interactive elements in this installation.

Discovering Control and Controlling the Environment

A key component of this installation was enabling users to control their environment by controlling the illuminated boxes. The footprint of the installation covered a substantial portion of the walkway, with the boxes changing the overall light levels in the walkway when fully activated. Users could control the light levels and change the experience of being in the walkway by controlling these boxes. The installation specifically left this control dynamic open to exploration so that users might discover for themselves how the system worked. There were no signs or additional cues that explained the purpose or functionality of the system. Additionally, when multiple users engaged with the installation together, shared control had to be negotiated. Users could block the display with their body or place their hand at the top of the display to effectively block others from controlling it.

Interaction Design

The on-sphere application consisted of eight wedges of different colours portrayed over the entire spherical surface. Each wedge had a coloured portion that could be moved like a slider to control the brightness of a corresponding box. When a user lifted their hand off of the sphere, the sliders would slowly return to the vertical halfway point, bouncing into place at the equator in about five seconds after touches were released. When the slider was lifted to the top of the sphere, the corresponding box would shine at full brightness, matching the colour on the wedge. When the slider was at the halfway point or below the box would faintly glow white. The boxes could display fifty alpha levels of brightness, creating a smooth transition between full brightness and the default state.

The sliders were designed to reset in this way to encourage continuous interaction with the sphere and create a more

dynamic experience. As the sliders reset, users could see more clearly the effects their input had on the boxes as they faded from full brightness. Additionally, users could play with the sliders as they continuously attempted to return to the default state. This resulted in an experience where the lights responded during direct touch on the sphere, creating a clear link between the glowing lights and users' touches.

When the system was left idle for 30 seconds, it would display playful prompts to encourage passers-by to approach. Firstly, the text "touch me" would spin and bounce around the equator of the display. This would be visible from a variety of angles as potential users passed by. Secondly, the wedges would playfully increase in a wave motion around the display. Each wedge would briefly increase its level in turn before returning to its default state. This resulted in each box around the circle pulsing with colour. This idle state aimed to communicate that the display was touch sensitive and that the wedges could move. The boxes lighting up also demonstrated to users that the boxes could change. The design of these cues was aimed to capture the curiosity of passers-by and encourage them to play with the system and discover its interactive qualities.

Hardware and Technical Setup

The deployment was completed using a commercially available interactive spherical display[3]. The display is constructed of rigid plastic with a diameter of 600mm, standing off the ground at a height of 1475mm tall. The screen is rear-projected from a single projector using a fish-eye lens situated at the base of the display. The resolution of the projector visible on the sphere is 1600x1600 pixels. The projector and all other internal elements are encased in a metal surround. The display supports multi-touch interaction using an array of infrared LEDs at its base. A camera captures input with fish-eye lens located at the base of the spherical screen and next to the projector lens. The camera images are used to track touches using blob detection at a 24 frames per second. The detected blobs are communicated using the TUIO protocol [9].

The interactive boxes were fabricated specifically for this installation. Each box was constructed of 4mm satin finish plastic that allowed for soft diffusion of the enclosed lights. Each box held a commercially available LED light element composed of 108 LEDs that combine to create a full spectrum of colour. The lights were controlled wirelessly using the DMX protocol[4]. All of the DMX signals were dynamically generated by the sphere using the mbed platform[5]. DMX commands were sent to the mbed microcontroller over a serial connection then transmitted to each box wirelessly using custom hardware paired with commercial wireless receivers/transmitters.

RESULTS

The installation was evaluated for three hours over the course of an evening on a pedestrianized walkway on the University campus. The evaluation was staged without an experimenter present and without any intervention by the research team during the deployment. The evaluation was completed without an experimenter present in order to observe users' undisturbed responses to the installation. During the evaluation, we collected video data and on-screen logging of touch input. The main goal of this evaluation was to reflect on our key design goals and analyse the success of the overall design.

Touch input logged during interaction was analysed by looking at each recorded touch point and unique touch events. Unique touch events consist of the series of touch points generated from the time the finger touches the display until it is lifted.

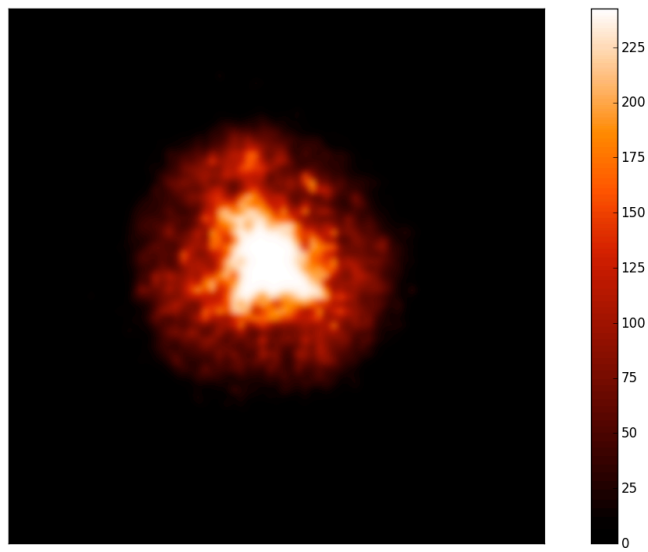

Figure 3. Heatmap of touch point distribution shows the majority of touches were at the top-centre of the display. These touch points are visualised in azimuthal coordinates, where the North Pole is at the centre and the South Pole is wrapped around the outer edges of the visualization.

Enter the Circle and Stay on Top

During the three-hour trial, the display logged over 163,200 touch events and over 18,300 unique touches. Figure 3 shows a visualisation of all the touch points visualised in azimuthal coordinates. The majority of the touch points are clustered around the North Pole, demonstrating that the top of the display can be useful for touch interaction.

The design of the wedge shaped sliders clustered input around the top of the display as this activated the most dramatic change in the interactive boxes. This type of interaction utilises the display space differently than many previ-

[3] PufferSphere® M by Pufferfish Ltd. http://www.pufferfishdisplays.co.uk/

[4] DMX Protocol for sound and lighting: http://dmxusb.com/

[5] mbed Microcontrollers: https://mbed.org/

ous applications, which make more frequent use of the central band of the display. For example, the gestures described by Benko et al. for a spherical display [3] and the peeking techniques presented by Bolton et al. [4] both primarily utilise the central band of the display around the equator. The top of the spherical display is interesting for interaction because it can be seen as a shared or communal screen space on the screen visible to the majority of users.

Exploring an Controlling Displays

The video data demonstrates a number of common behaviours observed around the display, as shown in Figure 4. For example, users frequently pointed from the display to the boxes, either to call attention to the general changes in the boxes or to share an understanding that they were in fact controlling the boxes, as shown in Figure 2. This fluid transition between display and environment was one of the key objectives of the design of this installation. Encouraging users to view a display as part of a larger ecosystem of interactive devices opens up new opportunities for interaction at and around public displays.

Spectators also made use of the implicit boundary of the stage, standing outside the ring of boxes to observe other people interacting with the display or taking photos of the installation as a whole, as shown in Figure 4, bottom. The installation was arranged as a ring to create a more physical boundary between stage and audience. However, not all users took notice of this stage boundary. For example, some passers-by walked through the ring while ignoring the installation. Ways of supporting non-use are also important considerations for the design of public interactions [2]. In order to mitigate negative experiences for those users who may chose to "opt out," there should be clear ways of avoiding interaction.

In a few cases, spectators specifically took on an audience member role around the installation by sitting on one of the interactive boxes to watch others interacting. Although this behaviour was not widely observed (Figure 4 middle was only 1 of 2 passers-by that exhibited this behaviour) it was still encouraging that our design afforded this action. The boxes were designed to resemble chairs in order to encourage the interesting behaviours often seen with chairs in public spaces [15].

It was observed that when large groups of users (greater than 10) used the display it was more common for others to begin crowding within the boundary of the boxes rather than outside of the boxes, as shown in Figure 4, top. This example shows around 20 users crowding around the display and the boxes, with varying body orientations and engagement with the installation. During busy times, users may begin to crowd to different areas of the installation and use the space in a wider variety of ways as seen in Fischer et al's work on large scale façades [7].

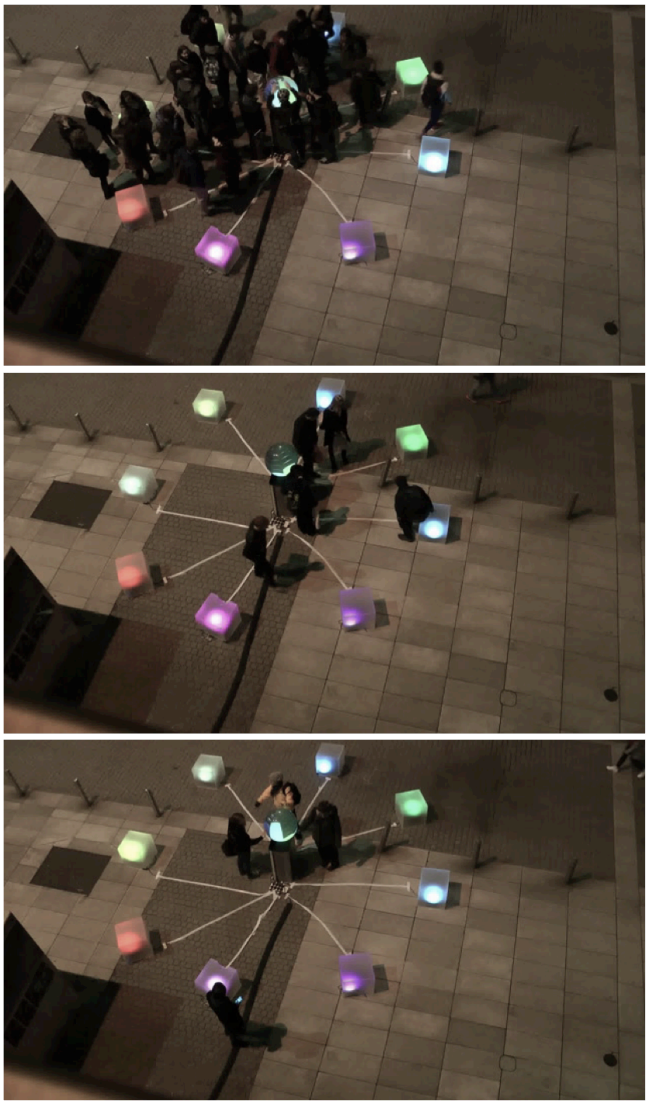

Figure 4. Passers-by played with the interface in a variety of ways. For example, large crowds of users gathered within the boundary of boxes (top), spectators sat on the boxes to watch others interact (middle), and spectators observed others from outside the ring of boxes (bottom).

DISCUSSION

The purpose of this evaluation was to explore the success of the overall design and reflect on opportunities to apply these dynamics more widely. Through this evaluation, we captured on screen logs and video data that shed light on the successes and failures in the concept and design.

The staging of the installation aimed to play with the visibility of stage boundaries, with the ring of boxes creating an implicit boundary between interactive and non-interactive spaces. An interesting direction to explore would be creating stronger boundaries, for example using markings on the ground or soft barriers such as rope. Designing the staging to be more explicit could create more memorable or intense experiences, but could also lower interaction rates.

The interactive boxes were designed to resemble chairs, but only a very small portion of passers-by used them as such. In this installation, the boxes were limited because there were cables running from each box to the centre of the installation. Giving these boxes more mobility, for example adapting the design to be completely wireless and adding wheels to the base, would give the opportunity to see more interesting uses of the boxes by passers-by. For example, users might move the boxes into different orientations or create their own stagings and layouts.

The installation explored control over one's environment and playful discovery of that control. However, based on observable data alone it is difficult to analyse users' impressions of the system after interaction. While some behaviour could be observed, such as pointing at boxes, it would be valuable to gather users' impressions through qualitative data collection. Additionally, different configurations of the boxes, for example randomly distributed, rotated 90º from the corresponding wedge, or directly in front of the line of sight of the wedge, would all lead to different ways of discovering and understanding control.

CONCLUSION

This paper presents the design and evaluation of a playful installation that brings together a spherical display with a set of interactive boxes embedded with lights. The display is staged at the centre of these boxes, where users must "enter the circle" to approach the display and interact. The design demonstrates promising future directions for playful installations and spherical displays. The results of an in the wild evaluation demonstrated that the majority of the touch input occurred on the top of the display, an area previously underused for touch input on a spherical display. The results also describe different behaviours observed around the display that resulted from the key design decisions that led to the creation of this system. Playing with staging, boundaries, control, and interaction with the immediate environment present exciting opportunities for playful interactions and novel installations for public spaces.

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