Williamson, J., Sunden, D., and Hamilton, K. (2016) The Lay of the Land: Techniques for Displaying Discrete and Continuous Content on a Spherical Display. In: PerDis '16: The 5th ACM International Symposium on Pervasive Displays, Oulu, Finland, 20-22 June, 2016, pp. 38-44. ISBN 9781450343664.

The Lay of the Land: Techniques for Displaying Discrete and Continuous Content on a Spherical Display

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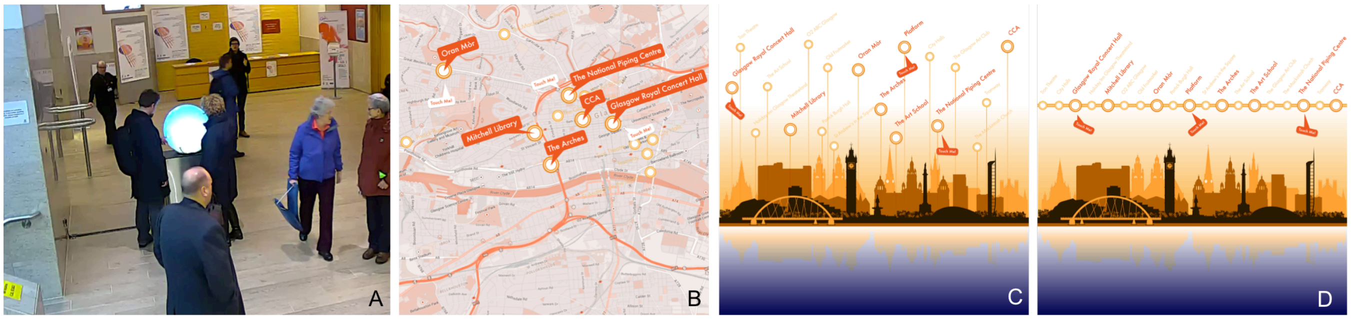

Figure 1. ***Venue Finder*** **is a spherical information display that provides information about concert venues during a city-wide music festival (A). The application uses three different techniques for distributing content across the display; map-based visualisation (B), a vertically distributed layout (C), and a linear layout (D).**

ABSTRACT

Spherical displays afford social interaction, where users can crowd around the display to explore content together. Related work has explored different aspects of public display interaction, but the distribution and layout of *content* is often ignored by researchers and users alike. We present *Venue Finder,* an interactive spherical display that provided information about concert venues during a city-wide music festival. We deployed *Venue Finder* in a comparative evaluation using three techniques to distribute content on the spherical display; map based, linear, and distributed. We deployed the display in a concert hall for six days per condition for a total of eighteen days. The results showed that the linear condition resulting in the longest interaction times and largest proportion of touches for content viewing. Based on our results, we propose three design recommendations for content distribution on spherical displays.

Author Keywords

Spherical Display, In the Wild Evaluation.

ACM Classification Keywords

H.5.m. Information interfaces and presentation (e.g., HCI).

INTRODUCTION

Spherical displays offer new affordances for social interaction that have exciting implications for public displays. The content on a spherical display is borderless but finite, meaning that *continuous* content can be displayed both vertically and horizontally. *Discrete* or *framed* content can be placed flexibly at different vertical heights around the display. Users can orientate their bodies towards each other and interact while maintaining eye contact and gesturing over the top of the display. Like King Arthur's round table, the display does not have an intrinsic *front* or *centre.* Users can approach from any side and interact simultaneously. Finally, the entire content of the display cannot be viewed from any given perspective since part of the display will always be facing away from the user. These affordances can be exploited to create unique user experiences at a public display, encouraging increased social interaction, revealing and hiding content across different areas of the display, and designing competitive and collaborative applications.

One of the major challenges of designing spherical information displays is how to present and distribute content on a spherical surface. Many of the techniques and metaphors designed for flat displays are difficult or inappropriate to apply to curved and spherical surfaces. For example, visual guidelines such as the left justification of columns and placement of menus [13] do not translate well to a spherical surface. A number of issues arise when determining how to place content on a spherical display. How do users interpret and explore content when the entire display is never fully visible? How should simultaneously interacting users experience content in different areas of the display? What are the most usable areas of the display for viewing and manipulating content?

There is limited previous work exploring issues of content layout on curved surfaces. Beyer et al. [4] discuss how users interact with frameless and semi-framed content on a cylindrical display. Their results demonstrate that adding frames creates distance between the content and the surface, influencing how users position themselves in front of a cylindrical display. Williamson et al. [18] evaluated how a spherical display was used in a public setting, comparing two techniques for content manipulation. That study explored where interaction occurred on the sphere, but geographically placed content restricted where information could be placed and content placement was not analysed.

In this paper, we explore three different techniques for distributing content on a spherical display through an in-the-wild deployment. We present *Venue Finder,* an interactive spherical display that provided information about concert venues during a city-wide music festival. We developed three techniques for distributing content on the sphere that exploited different affordances. First, we used a map-based layout, the prevailing metaphor for spherical displays. Second, we used a linear layout positioned just above the equator. Third, we used a distributed layout with content placed evenly at different vertical heights above the equator. We completed an unstewarded comparative evaluation of this display over eighteen days in a concert hall.

The main contributions of this paper are:

- A novel in-the-wild evaluation of three different techniques for distributing content on a spherical display, including a comparison of touch interactions for **viewing** content and **moving** content
- Demonstration that map-based layouts, the prevailing metaphor for spherical displays, lead to lower interaction times as compared to abstract visual layouts
- Design recommendations for distributing content on a spherical information display that combine discrete and continuous elements

RELATED WORK

Spherical Displays

Most previous work on spherical displays revolves around lab-based studies. Benko et al. [3] describe the design space of spherical displays, discussing the smooth transition from vertical to horizontal surfaces, the borderless but finite nature of the display, and the lack of a "master user" position. Bolton et al. [6] explored competitive and collaborative actions on a spherical display, developing different software based "peeking" techniques to support collaborative interaction. Pan et al. [10] evaluated interaction with an avatar on spherical and flat displays and found that trust was increased on the curved display over the flat display.

Williamson et al. [18] completed an in-the-wild evaluation of a spherical display, measuring how different interaction techniques influenced dwell time at the display. Their results showed that spherical displays using spin and tilt resulted in more usable screen space and longer interaction times than spin-only displays. One key limitation of this previous work is that touch interactions for *moving* content and *viewing* content were not analysed separately. Williamson et al. [19] explored how a spherical display could encourage playfulness in public spaces and discussed how cues such as idle states and distributed interactive elements could entice users.

Content on Public Displays

Related work has explored different aspects of public display content, such as how to curate content [21], how to interact with content at different distances [8], and how to present content using framed or unframed visuals [5]. Tomitsch et al. [15] evaluated how often users actually engage with content on public displays, demonstrating that nearly half of users exhibited playful behaviour before engaging with the actual display content.

The layout and distribution of content on public displays has not received significant attention in previous works. The visualisation community has a number of guidelines for organising and presenting content, for example using contrast, depth, and relative positioning of objects [17]. Many of these techniques can aid the visual design of information displays, but do not provide clear guidelines specifically for laying out content on a sphere. User interface guidelines such as [14] are even more problematic as they are often built on the assumption of flat displays with windowed environments. Guidelines for where to place content on a spherical display are needed to inform the design of spherical information displays.

Evaluating Displays in the Wild

Evaluating technology outside of the lab in real world public spaces has clear advantages but requires specific metrics and techniques. Alt et al. [2] describe different techniques for evaluating public displays, including ethnography, "asking users", lab studies, field studies, and deployments.

Peltonen et al. [11] evaluated *CityWall* using a combination of interaction logs, video data, and on-site interviews. This popular approach has been used widely, such as in *StrikeAPose* [16] and *Media Ribbon* [1]. Kukka et al. [9] extended this by using on-screen questionnaires to gather demographic information and subjective feedback. Claes et al. [7] describe a method for controlling evaluations of displays in the wild. This uses a public setting to complete lab-style evaluations, recruiting participants from passers-by. Williamson et al. [20] describe a method for covert evaluations of public displays in the wild without experimenter intervention. This approach was used to evaluate interfaces like *WaveWindow* [12], *Enter the Circle* [19], and *GlobalFestival* [18].

VENUE FINDER: AN INFORMATION DISPLAY FOR A CITY-WIDE FESTIVAL

Venue Finder is a spherical information display that provided information about concert venues during a city-wide music festival. We completed an in-the-wild comparative evaluation of three techniques for distributing content on the sphere over an eighteen-day deployment.

Venue Finder

Inspired by previous work [4,18], *Venue Finder* explores different techniques for distributing content on a sphere. Beyer et al. [5] discuss frameless and semi-framed content on a curved display, where frames can serve to create distance between content and the display surface. *Venue Finder* combines continuous **background content** (frameless content) with discrete **pop-up content** (semi-framed content) to explore this further.

The *Venue Finder* application provided pop-up content for six concert venues. Users could toggle the pop-up content on or off by tapping the button below the venue name. Pop-up content would automatically close after thirty seconds. Users could explore the information display by manipulating the background content horizontally and vertically. *Venue Finder* provided visual feedback for active touch points and visual and audio feedback when pop-up content was accessed.

After fifty idle seconds, the display content "bounce back" to its default vertical position, maintaining its current rotation. After sixty idle seconds, the application started an animated idle state. In this mode, the entire content would spin slowly, with bouncing "Touch Me" flags appearing randomly next to pop-up content.

Content distribution

We trialled three different techniques for distributing content around the display; a map-based layout, a linear layout, and a vertically distributed layout. These layouts were designed based on prevailing metaphors for spherical displays, frequency of interaction in different regions of the display, and coverage of display screen space. Each layout placed the majority of content above the equator because previous work has shown that relatively little interaction occurs below the equator [18]. Each condition portrayed the same information, using the same resources for pop-up content, interaction cues, and visual/audio feedback.

The map condition used map-based background visuals and presented geographically placed information. The linear and distributed layouts used stylised background visuals with arbitrarily placed information. The only difference between the linear and distributed layouts was the position of information on the display. These conditions provide a comparison between map-based metaphors for spherical displays and more flexible abstract layouts.

Map Layout

Map layouts are the prevailing metaphor for spherical displays. For *Venue Finder,* we used a map of the city adjusted for viewing on a sphere, as shown in Figure 1, Panel B. This section was chosen to distribute content as evenly as possible across the display given the venues' real physical locations. When using a map-based layout, designers are limited by physical geography when laying out content. Adjusting the position of content in this context could render map layouts unreadable or geographically incorrect.

Linear Layout

The linear layout placed pop-up content at a constant vertical height in a ring around the display, as shown in Figure 1, Panel D. A horizontal line was used to connect content around the display. Because a non-map based layout does not impose external geographic constraints, content can be placed anywhere. For example, the layout can be designed to ensure occlusion does not occur. This linear design evenly distributed content and gave all pop-ups similar visibility and accessibility. The background content was styled in a contemporary cut out design featuring local iconic landmarks, as shown in Figure 1, Panels C and D.

Distributed Layout

The distributed layout placed pop-up content at different vertical heights in a band around the display, as shown in Figure 1, Panel C. Vertical lines were used to connect content to the base of the display. Placing content at different vertical heights utilised a greater area of the display for content presentation, but could also result in content appearing in less frequently used areas of the display and some occlusion could occur when multiple content windows were opened. The background visuals were the same for the linear and distributed layouts.

IN THE WILD STUDY

The *Venue Finder* application was deployed in a comparative evaluation where each condition was shown for six days for a total of eighteen days deployment. The display was placed on the ground floor of a large concert venue next to a café and festival vendor stalls. The conditions were automatically changed at the beginning of each day in counterbalanced order. The installation was specifically staged without any experimenter presence in order to evaluate undisturbed interaction [20].

Condition	Touch Data Points	Unique Touches	Content Opened	Content Closed
Map	600,989	66,385	2,986	1,510
Linear	324,233	32,423	3,751	1,341
Distributed	427,546	51,523	3,801	1,771

Figure 2. A summary of the data collected from touch logs and interaction logs is given for each condition.

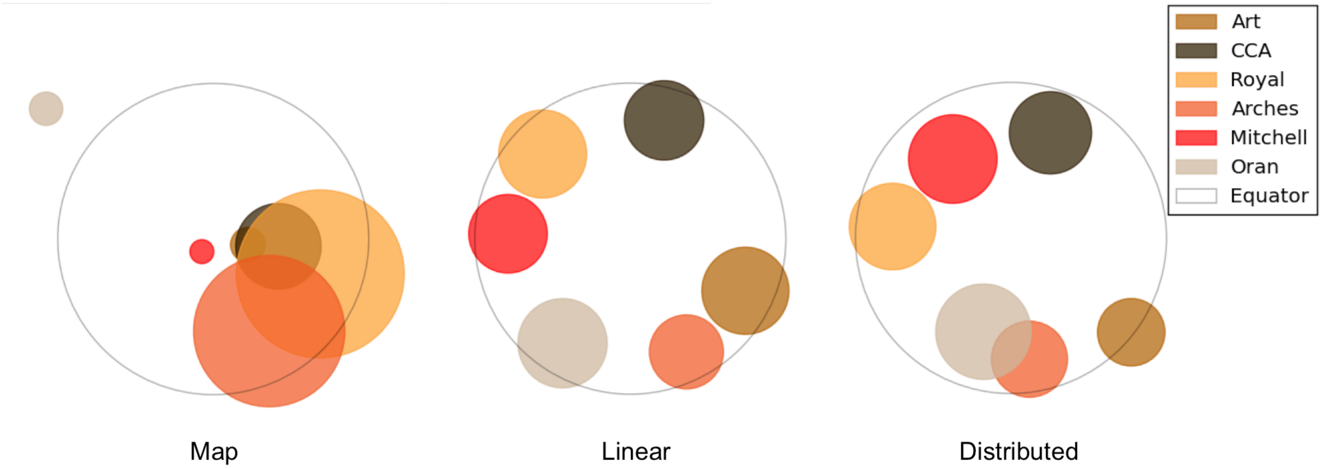

Figure 3. This figure illustrates the frequency at which pop-up content was interacted with for each condition. The diameter of the circle represents the frequency of pop-up content interaction. Each circle is centred on the pop-up content's position relative to the background content. The grey line represents the equator.

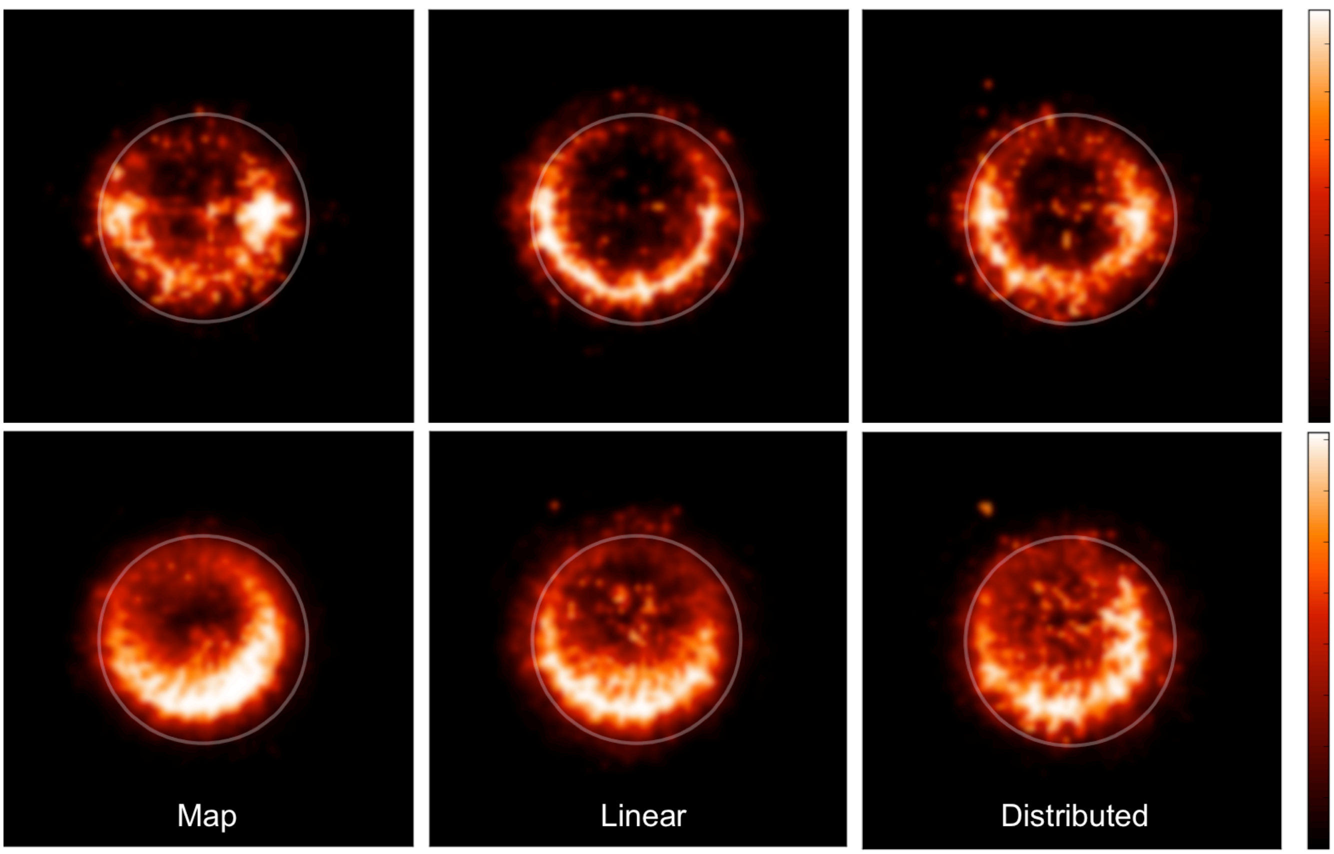

Figure 4. This figure illustrates the touch points based on their physical location on the sphere. The top row shows touches from interaction with pop-up content and the bottom row shows touches from interaction with background content. The white line represents the equator.

RESULTS

The results are based on activity and touch point logs generated by the *Venue Finder* application and video data collected during select days of the deployment. The data includes 1,347,571 touch data points, 119,811 unique touches, and 15,160 interactions with pop-up content. A breakdown of these values for each condition is given in Figure 2. Video data was also analysed for a portion of the deployment, including a total of 268 interacting users (108 for linear, 70 for distributed, and 90 for map). Results are visualised in azimuthal projection, where the "North Pole" of the display is visualised in the centre and the "South Pole" is visualised on the outer edge, as shown in Figures 3 and 4.

The study was completed using a commercially available interactive spherical display[1]. The sphere is made of rigid plastic that sits on an enclosed aluminium and steel stand. The display stands 1.47 meters tall, with a diameter of 60 centimetres and a visible resolution of 1600x1600 pixels. The sphere uses an infrared camera at the base of the display to support multi-touch interaction.

Where is the Content? Successful Content Placement

Figure 3 shows the frequency with which the pop-up content was accessed based on its position relative to the background content. In the linear and distributed conditions pop-up content was accessed at similar frequencies. The map-based condition shows a substantial difference in the access frequency of different pop-ups. Content located too far above or below the equator was accessed less frequently than content closer to the equator. For example "Mitchell Library" (red circle) and "Oran Mor" (grey circle) were both accessed substantially less frequently than "Royal Concert Hall" (yellow circle) or "The Arches" (orange circle). Content in the map based condition may also have suffered due to occlusion, such as "CCA" (dark brown circle) occluding "The Art School" (light brown circle).

What to Touch? Window Activity and Manipulations

There is a substantial difference in the proportion of touch interactions with background content and pop-up content between the map-based condition and the linear and distributed conditions. In the linear and distributed conditions, 15% and 11%, respectively, of unique touches were used to interact with pop-up content. In the map condition, only 7% of unique touches were used to interact with pop-up content. The greater visual complexity of the background in the map condition may have led to more playful interaction with the display, for example users searching for local places. It also may have been more difficult to perceive pop-up content against the more complex background, even though the visual design maximised contrast to ensure visibility of interactive content.

Where to Touch? Comparing Static and Dynamic Touch Locations

Figure 4 shows the distribution of touches based on their physical location on the sphere. These are separated into touches for interacting with pop-up content (Figure 4, top row) and touches for interacting with background content (Figure 4, bottom row). This separation of touches for viewing pop-up content and for moving background content has not been analysed in previous work. A key observation is that touches for **viewing** content occur over a much smaller area than touches for **moving** content. In all three conditions, content was seldom viewed in areas near the very top of the display, although actions for moving content did occur in these areas.

[1] Pufferfish Displays PufferSphere M - pufferfishdisplays.co.uk

Figure 4 demonstrates that the map condition used the largest area of the screen (Figure 4, top left) and the linear condition used the smallest area of the screen Figure 4, top middle). Interaction with background content was relatively similar across all conditions, although the map condition shows some preference for interaction around the equator over interaction at the top of the display. The relatively less dense areas seen in the top of each visualisation were caused by the presence of a wall roughly two meters away from the display, resulting in relatively fewer users on that side of the display.

Why Interaction? Social Behaviour Around the Display

Manual video analysis of 268 interacting users was completed using an excerpt of video data from the first day of deployment for each condition. The results show that the average interaction time for the linear layout was 28 seconds (standard deviation of 31 seconds), distributed layout was 33 seconds (standard deviation of 32 seconds), and map layout was 23 seconds (standard deviation of 20 seconds). Using the non-parametric Mann-Whitney test to complete pairwise comparisons of interaction times for each condition, the results show that there was a significant difference between the linear and map based layouts ($p<0.05$). This was the only comparison with significant differences.

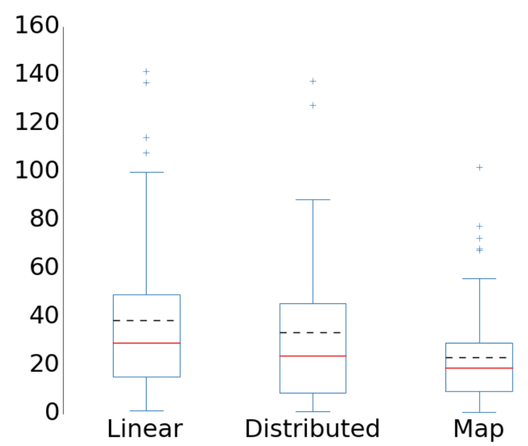

Figure 5. Box plots of interaction times in seconds for each condition. The difference between the linear and map conditions was statistically significant.

DISCUSSION

In map-based visualisations, external constraints often determine where content can be distributed around the sphere, which can lead to poorly distributed content. While the map condition encouraged more interaction with background content, the pop-up content was accessed proportionately less than in the linear and distributed layouts. Although absolute numbers are difficult to place into context without total user numbers, the conditions were counterbalanced to mitigate differences in pedestrian traffic across deployment days.

Even though the map condition logged 105% more unique touches than the linear condition, this still resulted in lower absolute numbers of interactions with pop-up content. The observed 12% increase in interactions with pop-up content between the map condition and distributed condition implies that this content was more successfully accessed in the distributed condition. Additionally, users spent significantly less time interacting with the map based layout than the linear layout. Users of the linear layout engaged with more content and for a longer length of time than users of the map-based layout.

Interaction with the linear layout was arguably the most successful condition, with the longest interaction times and the largest proportion of touches for viewing content. Although this condition did not utilise the largest area of the screen, the equal visibility of interactive elements and horizontal trajectory of content clearly made content more usable and easily accessible. The horizontal lines used in this layout likely enticed users to seek content **around** the display, leading them to quickly discover previously unseen content by simply following a horizontal path. This result is in line with similar studies on cylindrical displays [4], where designing for interaction while walking around the display improved user experience. The horizontal lines in the linear layout (as compared to vertical lines used in the distributed layout) acted to draw users' focus to additional content.

Overall, pop-up content access represented a relatively small proportion of interactions, ranging from 7% to 15% depending on the condition. Users' desire to "play" instead of actually browse content is a well-documented phenomenon in public displays [15]. In our deployment, content was mainly peripheral to the festival and more for pop-culture interest as opposed to serious information needs. For example, in the context of an airport information display, successfully communicating information may be of more importance.

DESIGN RECOMMENDATIONS

DR1: Pop-up content should be distributed between the equator and 50º above the equator.

DR2: Abstract background content should be paired with content flowing horizontally around the display.

DR3: To increase interaction with pop-up content, background content should be as simple as possible, using plain visual elements.

CONCLUSION

Venue Finder was a spherical information display that explored different techniques for distributing content across a spherical surface. We completed an in the wild comparative evaluation of *Venue Finder* over eighteen days during a city-wide music festival. The results of our study show that map-based layouts, the prevailing metaphors for spherical display content, led to the lowest interaction times and the least proportion of touches for viewing content. Based on these results, we recommend that content should be distributed in the band between the equator and 50º above the equator. Additionally, visual design should include cues for content distributed horizontally around the display, which can be used to increase interaction times and proportion of touch interactions for viewing content.

ACKNOWLEDGMENTS

This research was funded by the EPSRC SIPS Project (EP/M002675/1) with generous support from Pufferfish LTD and the Glasgow Royal Concert Hall.

The dataset underpinning this publication is available at: http://dx.doi.org/10.5525/gla.researchdata.307.

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