Full Body Interaction beyond Fun: Engaging Museum Visitors in Human-Data Interaction

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Abstract
Engaging museum visitors in data exploration using full-body interaction is still a challenge. In this paper, we explore four strategies for providing entry-points to the interaction: instrumenting the floor; forcing collaboration; implementing multiple body movements to control the same effect; and, visualizing the visitors' silhouette beside the data visualization. We discuss preliminary results of an in-situ study with 56 museum visitors at Discovery Place, and provide design recommendations for crafting engaging Human-Data Interaction experiences.

Author Keywords
Full-Body Interaction; Human-Data Interaction; Museums

Introduction
In recent years, the wide availability of motion tracking devices, such as Nintendo Wii and Microsoft Kinect, has opened a range of opportunities for the design of full-body installations in museums and public spaces. One of the argument in support of the use of gestures and body movements to control museum installations is that they create engagement and fun [5]. For example,

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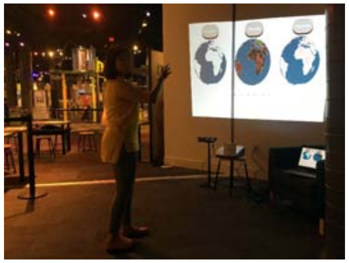

Figure 1: A museum visitor interacts with a prototype data visualization using gestures.

Puppet Parade[1] allows children to puppeteer creatures that are displayed on large projected walls [8]; Metamorphosis allows visitors to go through the stages of a butterfly's metamorphosis using "engaging ubiquitous technologies" [7]; Word Out! is an interactive game (designed to facilitate the learning of alphabet letters) that uses full-body technologies to "stimulate fun and engagement" [11].

The assumption that full-body technologies themselves are engaging for people, however, is not always true. People generally interact with museum exhibits for less than two minutes [14] and, if they are not able to quickly understand how to operate with a full-body installation, they often leave thinking that the system is broken [3]. This is particularly problematic when visitors are exposed to interactive installations for data exploration, as in the case of Human-Data Interaction (HDI) [1,2] -an example is illustrated in Figure 1. Exploring data offers a deep contrast with being a puppeteer or playing with butterflies: it is not a stereotypical example of "fun" activity, especially for young visitors. If we want HDI installation to be self-standing, and to attract visitors of different age groups without the help of museum docents, we need to identify engaging entry-points to the interaction. In this paper, we report preliminary results and observations from a study that we conducted at Discovery Place, a science museum in Charlotte, NC. Specifically, we explored four strategies for providing entry-points to the interaction: instrumenting the floor; forcing collaboration; implementing multiple body movements to control the same effect; and, visualizing the visitors' silhouette beside the data visualization. We provide design recommendations and outline future research for crafting self-standing, engaging HDI installations.

[1] http://design-io.com/projects/PuppetParadeCinekid/

Related Work

Human-Data Interaction (HDI)

Human-Data Interaction (HDI) is a term that was initially introduced in [2] and [1] to refer to interactive museum installations that allow multiple people to collaboratively explore large sets of data using hand gestures and body movements. Subsequently, the definition of HDI has been extended in [9], [6] and [93] to include the process of making big sets of data (e.g., data streams that generally undergo long data mining processes) accessible to a broader audience. This democratization process aims to move large datasets out of research labs (the domain of data scientists), into public spaces and informal learning settings, such as museums.

Personalization as an Entry-Point to HDI

Personalization has been used as a way to provide an entry-point to interacting with data. It incorporates the idea that allowing visitors to select "their own" data that they want to explore creates a personal connection with the data, which facilitates engagement [4] and learning [13]. This strategy, however, requires visitors to spend some time at a kiosk, before entering the main interactive space. This may disengage visitors because of the length of the "preliminary" configuration work that they have to undergo, or simply not be feasible in some exhibit spaces.

Using Silhouettes to Support Engagement

Snibbe et al. suggest to use bodies to control projected shadows in social spaces [16]. Shoemaker et al. propose to incorporate users' silhouettes on top of the

Figure 2: Experimental setup that we used for this study. Our system (IDEA) included a data visualization projected on a 65" screen, a Microsoft Kinect, and some instrumentation of the interaction space (e.g., we use a yoga mat to highlight the area in which users were able to control the timeline).

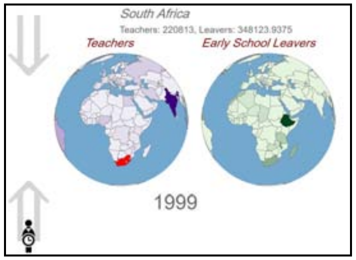

Figure 3: Screen shot of the interactive data visualization for IDEA. It can be accessed at Visualization Web Link.

user interface [15]. Although engaging, this approach covers a portion of the visualization, which would limit the learning opportunities offered by HDI installations (for example, it would be difficult to compare two datasets, if one is covered by the user's shadow). Looking Glass [10] recommends to incorporate people's silhouettes in order to design engaging shop windows. In this paper, we explore how the idea of incorporating visitors' silhouettes can be applied to the design of engaging HDI experiences for informal learning.

Application Scenario: IDEA

"Interactive Data and Embodied Analysis" (IDEA) is a prototype installation that allows museum visitors to use their body to explore large datasets -see Figure 2. IDEA comprises of interactive data visualization on a large screen and a 4mx4m interaction space in front of the screen. We used C++ (to control the Kinect) and JavaScript (for the data visualization) to create a custom-made application. Visitors can move within the interaction space to interact with the artifact.

IDEA: Data Visualization

The screen contains the geospatial representation of data projected on a globe with color gradations across countries (Figure 3): a darker color for a country represents a higher value of the corresponding data. The datasets include variables of general interest like forest coverage, GDP, tourism, number of school teachers, number of early school droppers, and number of literate people for a country. These variables were selected from United Nations Environment Program database http://geodata.grid.unep.ch/. All variables are available from year 1999 to 2014. Each variable is represented on individual globe, two at a time.

The visualization is interactive and allows the following functionalities:

- *Rotation (start and stop):* The globes continue to rotate at a predefined speed. They can be stopped to focus on a particular country, and the rotation can again be re-started by the user.
- *Time-line (move forward and backward in time):* The time line depicts all the data for a particular year. As the time line is moved, the data on the globe gets updated, adjusting the color gradients corresponding to the data values.
- *Exploration (Get Detailed Data about One Country)*: Navigating over a country displays the precise values of the variables for that country and the selected year in textual format.

The users are assigned different controls. User 1 is assigned control of Rotation and Time-line, while user 2 is assigned control of Exploration. The assignment takes place on first-to-enter-the-space basis.

IDEA: Interaction Space

The interaction space is an isosceles trapezoidal space in front of the projected screen, with the shorter base length at 1.0 meters and longer base length at 2.7 meters from the Kinect sensor. The height of the sensor is 1.0 meter. We marked three zones on the floor (Figure 2). The zones are labeled using colored non-slippery yoga mats and textual labels indicating the functionality that people can control in that area. For instance, the zone that enables the change in years (time-line) is marked as "TIME" as well as covered with a yellow colored mat and the user who is assigned the time-line control moves *only* in her/his zone. Visitors can move from one location to another, within a zone or across zones (depending on the control assigned). In

IDEA Functionalities	Controlling Body Movements
Stop the Globe Rotation	Stand Still on the “STOP” zone
Start the Globe Rotation	Stand Still just outside the “STOP” zone
Increase the Year Value	Take Forward steps in “TIME” zone
Decrease the Year Value	Take Backward steps on “TIME” zone
Hover over Country and Obtain Detailed Valued about that Country	Walk within the Interaction Space

Table 1: Body Movements used to Control IDEA

IDEA, we focused on movements from left to right, front and back, staying still at one location (Table 1).

Methodology

The goal of this work is to identify the challenges that users face when using the system with minimum instructions, in order to provide design recommendations for crafting interactive installations for data exploration that visitors can find engaging, even without the intervention and support of museum interpreters. In order to do that, we explore four alternative strategies for providing entry points to the interaction:

(1) instrumenting the floor;
(2) forcing collaboration;
(3) implementing multiple body movements to control the same effect;
(4) visualizing the visitors’ silhouette beside the data visualization.

We conducted naturalistic observations of visitors’ interaction with the prototype. The interaction between researchers and visitors was minimal: a notice that visitors were entering a video-recorded area and a study information sheet were on display at the entrance of the interaction, and two moderators were available to answer questions that visitors may have about the study or the installation. Specifically, we let the people explore the system all by themselves and observed and video recorded their interaction. We used a semi-experimental design, in order not to interfere with the way in which visitors generally experience museum installations: people were able to interact with the variation of the IDEA prototype that was on display during their visit. We then used the videos from the study sessions to find the *Interaction Time,* defined as the time spent by the users with IDEA. Ideally, we would like visitors to interact with IDEA for as long as possible, in order to discuss data to a larger extent.

Results & Discussion

A total of 56 visitors participated to this study, which we conducted at Discovery Place, a science museum in Charlotte, NC. All study sessions were videotaped. In the following, we report preliminary results and observations from our study, which we believe can be useful for the design of engaging HDI experiences.

The First Fifteen Seconds are Crucial for the Interaction
As we expected, users spent some time understanding how the artifact would respond, before being able to instrumentally operate with IDEA. In particular, we called O*n-Boarding Time* of the participant the time taken by the user to understand how the interaction works. This allows the users to understand the mapping between their movement within the interaction space, and the artifact response. We observed that, even though the interaction seemed novel, the users who were not able to guess how to operate with the system after attempting for 10 to 15 seconds all gave up, frustrated that the system could not map their movements to the visualization. Thus, the first 15 seconds are crucial when creating engaging HDI installations. It is worth noting that this time is significantly shorter than the two minutes visitors generally spend with traditional exhibits [14].

Floor Controls are not an Entry-Point to the Interaction
We found that all our participants initially did not understand that the floor was the interaction media. Even though we placed some colorful mats and labeled the location (see Figure 2) people did not look at the

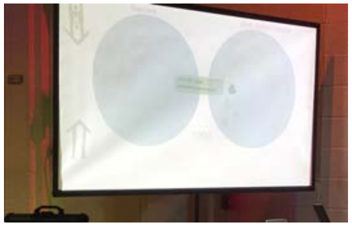

Figure 4: In the "Forcing Collaboration" strategy, the screen becomes active only when there are 2 users in the interaction space.

Figure 5: Silhouette that we used as mouse cursor in the Avatar condition (Image Link)

floor in the first instance. The data visualization was the primary focus even though areas of the floor were clearly marked and color coded. Thus, instrumenting the floor does not seem to be a viable entry-point to the interaction: it was not enough for our participants to understand that the system was interactive (rather than being static data visualization).

Forcing Collaboration is not an Entry-Point to the Interaction

Fostering collaboration and conversations among diverse groups of visitors is essential to create engaging learning experiences in museums [12,13]. Thus, we designed IDEA to encourage collaboration among two users at any given time. The start/stop and time-line control is given to one user, while navigation control is given to another user. The user entering the interaction space first is assigned the controls of start/stop and time-line; the second user is assigned the navigation control. In the case where two users enter the space simultaneously, the controls are assigned randomly. We programmed IDEA to track 2 users and send corresponding signals to the data visualization (Table 1). Because of the benefit of supporting collaboration, we tested two variations of the IDEA prototype: Forced Collaboration, and Non-Forced Collaboration. In the Forced Collaboration condition, we wanted to explore if forcing collaboration since the beginning of the interaction would be a viable entry point to the interaction itself (see Figure 4). The system initially forced the participants to enter in groups of two (we tested this system configuration with 26 visitors). If the sensor detected less than 2 users on the floor, a message was displayed on the screen saying "I *cannot see 2 users on the floor*". This experimental condition was aimed to enforce collaboration and team based data exploration. We expected visitors would have actively looked for a friend or companion to be able to "activate the system." Contrarily to our expectation, forcing collaboration was not a viable entry-point to the interaction. We observed that this did not encourage users to interact with IDEA. Some of the users left the interaction space instead of calling for a partner: out of 26 participants, eight left without even interacting with IDEA. In the Non-Forced Collaboration condition, we allowed people to operate with the system even as solo users. In this latter condition, we did not observe this phenomenon anymore.

Implementing Multiple Controlling Actions for the Same Functionality is an Entry-Point to the Interaction

In IDEA, the time-line displays the icon of a person (see Figure 3). Our original idea was to make the icon move up and down as the user moves forward and backward on the time-line area on the floor. We decided, however, to use the Kinect to track the neck joint rather than the torso, so that people were potentially able to control the timeline also with more subtle head movements. Interestingly, we observed that 6 users figured out alternative ways to move the timeline, which was by jumping up and down, swaying side by side, or rocking back and forth without moving their feet. Thus, including multiple ways of interacting with the same system functionality seem to be an effective entry-point to the interaction, as people have more chances to guess how to operate with the system.

Displaying the Visitors' Silhouette is an Entry-Point to the Interaction

When people move through the interaction space a navigation control (i.e., a cursor) moves with visitor up,

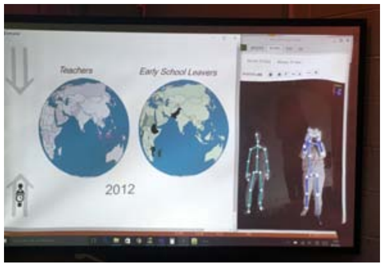

Figure 6: The "Mirror" condition showing the digital reflection of the users on the side of IDEA visualization.

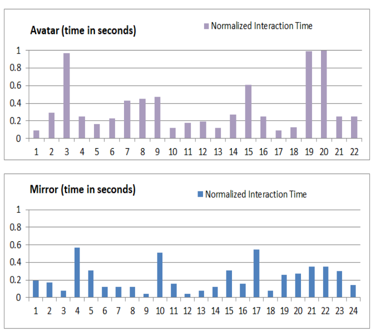

Figure 7: Interaction Time for Mirror and Avatar conditions. The X-axis contains the participant IDs: Avatar – 22 participants; Mirror-24 participants. The actual data value in second for each participant has been normalized to lie between 0 and 1 by dividing with the highest noted value across both groups, primarily to show the trend of increase in time.

down, left, right. When the user walks (i.e., moves the cursor) on a country, IDEA visualizes a popup screen with additional data for that country. We tested two alternative ways of incorporating a representation of the visitor into the data visualization interface, in order to create a correspondence between visitors' movements and navigation control: *Avatar*, and *Mirror*.

In the *Avatar* condition, we replaced the mouse cursor with a standard picture, with a person silhouette (Figure 5). We observed that the user could barely see the cursor moving. It took several attempts for the user to point out where the cursor was on the map. User responses like, "*where am I going?", "How does this thing work?"* and "*Is anything happening?"* along with random movement on the floor, demonstrated that the cursor, which works well for desktop systems, failed to provide the feedback for body movements.

In the *Mirror* condition, we displayed visitors' silhouette (together with tracking information), in real-time, beside the main data visualization (Figure 6). The users could see their own silhouettes on the right side of the screen with the rest of interactive visualization on the left side of the screen. An paired t-test was conducted to compare users' interaction time in the Mirror vs. Avatar conditions; there was a significant difference in interaction time under Avatar (X=28.29, SD=19.58) and Mirror (X=45.41, SD=36.31) conditions, $p<0.03$. Thus, we observed that the average interaction time with the system was significantly higher in the *Mirror* condition (Figure 7). In general, higher interaction with the system denotes that people are spending more time with it, which could maximize data exploration. We noticed, however, that visitors were more interested in seeing themselves on the screen rather than with the exploring the artifact: e.g., people tended to spend more time dancing and moving their bodies with minimal intention to interact with data.

Thus, introducing a live representation of the users (rather than a standardized avatar) provides an effective entry point to the interaction. It may, however, be distracting. Using silhouettes that mimic the user's body movements on the screen, but that are just slightly bigger than traditional mouse cursors, may provide an interesting compromise. Such silhouettes should appear immediately as the user enters the interaction space and should leave with the user, and may be displayed on a side portion of the screen, or used as an alternative to more traditional navigation controls. These design ideas should be further investigated in future work.

Conclusion and Future work

In this paper, we observed that engaging museum visitors in data exploration is an open challenge, and we explored different strategies to provide an entry-point to the interaction with HDI installation. In the upcoming work, we will generate alternative prototypes to further evaluate the entry-points that we identified in this paper. We would also like to experiment with different technologies (e.g., displaying the data visualization on the floor), and assess the relationship between engaging and learning when visitors interact with data.

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