Situating Approaches to Interactive Museum Guides

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(Received 1 May 2008; final version received 29 July 2008)

This paper examines the current state of museum guide technologies and applications in order to develop an analytical foundation for future research on an adaptive museum guide for families. The analysis focuses on three critical areas of interest in considering group and social interaction in museums: tangibility – the role of tangible user interfaces; interaction – visit types and visit flows; and adaptivity – user modeling approaches. It concludes with a discussion of four interrelated trajectories for interactive museum guide research including embodied interaction, gameplay, transparent and opaque interaction and the role of personal digital assistants.

Keywords: museum guides; adaptive museum guides; tangible user interfaces; museum user models; group interaction; visitor experience; digital heritage

Introduction

Museum technologies have increasingly become the focus of research in such areas as ubiquitous computing, tangible computing and user modeling. Since the advent of audio-based museum guides, much research and development has been placed on increasing the technological capacity for augmenting the museum visit experience. Early prototypes such as Bederson (Bederson 1995) provided evidence that it is possible to support visitor-driven interaction through wireless communication, thus allowing visitors to explore the museum environment at their own pace. More recent prototypes and fully functional systems are much more complex, supporting a variety of media, adaptive models and interaction modalities. However, as Bell notes in her paper on museums as cultural ecologies: 'The challenge here is to design information technologies that help make new connections for museum visitors' (Bell 2002). Bell further argues for the importance of *sociality* in museums, where visits are as equally social and entertaining as they are educational. Addressing the social qualities of a museum visit remains a clear challenge to designing with museum guide technologies. While families are by far the most common visitor type to science, history and natural history museums, few systems are designed for families.

In this paper, we describe our theoretical analysis of the current state of museum technologies and adaptive museum applications in order to provide a detailed understanding in support of our current research goals. We have narrowed our focus to three critical trends in adaptive museum guides that form the theoretical anchors of our future research. The areas include: tangibility, interactivity and adaptivity. We conclude with a discussion of research trajectories and their benefits. We believe this paper provides a

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critical summary of electronic museum guides of the last decade and outlines key areas of concerns for academic researchers.

Background

At this stage in our research in adaptive museum guides we are exploring how best to address issues of social engagement, play and learning for groups of visitors such as families. Our early research in the sociality of mobile devices (Wakkary et al. 2001) and technical systems in support of virtual and adaptive learning (Richards and Hatala 2005) led us to the design and technical research of museum guides. Previously, we researched a prototype tangible and adaptive museum guide system known as *ec(h)o* that we discuss at several points in this paper. The aims of the research included evaluation of the role of tangibility and play in user experience (Wakkary and Hatala 2006, 2007) and evaluation of user modeling (Hatala and Wakkary 2005; Hatala, Wakkary, and Kalantari 2005). In exploring tangibility, we researched how we could integrate our tangible user interface with visitors' playful and curious engagement with physical interactives in a museum. Our research in user models extended work on museum visitor types in which different patterns of museum visits by different visitors can be described in user profiles. We used ambient and stereoscopic audio to display information to users of our system. This created a novel interface but, because users were required to wear binaural headphones, it had the serious drawback of limiting social engagement.

In response to the inherent antisocial aspects of *ec(h)o*, we researched an embodied interaction prototype known as *socio-ec(h)o*. Embodied interaction systems treat the physical world as a *medium* rather than a *metaphor* as in virtual three-dimensional (3-D) environments. Embodied interaction systems are both tangible and social as they 'are manifest in our environment and are incorporated in our everyday activities' (Dourish 2001). *Socio-ec(h)o* comprised a prototype environment for group play. The research goals were to explore the design of an embodied interaction system utilizing ambient lights and audio, a method for composing group user models and group interaction utilizing a game structure. Relevant research to date has focused on the technical platform (Wakkary et al. 2005), interaction and gameplay (Wakkary et al. 2005, 2007), group interaction (Wakkary et al. 2008) and user group models (Jiang 2008). While this project did not take place in a museum setting, it enabled us to extend research issues from *ec(h)o* into issues of sociality and group collaboration.

Our most current research, a project named *Kurio*, motivates this present discussion on tangibility, interactivity and adaptivity. *Kurio* is a museum guide system aimed at families and friends visiting the museum. In *Kurio* a family imagines themselves as time travelers lost in the present because their time map is broken. In order to repair the time map, family members complete small tasks and collect information from the museum reconstructing the time map each time. In addition to the game-like interaction, the interaction design and underlying user group model are based on a constructivist-learning model. The user group model relies on the constructivist schema to adapt to the different learning behaviors of each family member and assign appropriate tasks to each member. The interactive museum guide itself is distributed over a number of different components, tangibles, a tabletop computer and a personal digital assistant (PDA). The main component is a set of tangible computing devices we designed. Overall we have five tangibles including a *pointer* for selecting museum artifacts; a *finder* for finding different locations in the exhibition space; a *listener* for hearing audio files in different locations in the exhibition space; a *reader* for collecting text from didactic displays; and a *gesturer* for mimicking and collecting gestures relevant to different artifacts on display (see Figure 1). At this stage it is too early in the research to report on the design, assessment or findings. Rather, we describe the project to discuss what motivated the theoretical discussion in this paper. The analysis reported here is a result of our theoretical discussion and rationale that preceded the design of *Kurio.*

Situating tangibility in museums

Tangibility, or tangible user interfaces (TUI), imbue physical artifacts with computational capabilities. Hiroshi Ishii and Brygg Ullmer introduced the notion with the salient phrase of 'coupling of bits and atoms' (Ishii and Ullmer 1997). By their own account, scientific instruments from a museum collection at Harvard University inspired them. They experienced a quality of aesthetics in the oak and brass instruments on display that, in their minds, have been lost with the advent of computing. It became their aim to 'rejoin the richness of physical world with HCI [human–computer interaction]' (Ishii and Ullmer 1997). Ishii and Ullmer's idea of tangible computing built on earlier work on graspable interfaces (Fitzmaurice et al. 1995) and real-world interface props (Hinckley et al. 1994). They describe TUIs as the 'seamless coupling of everyday graspable objects (e.g. cards, books, models) with digital information that pertains to them' (Ishii and Ullmer 1997). Later they refined and expanded the definition of TUIs to include:

1. Physical representations are computationally coupled to underlying digital information;
2. Physical representations embody mechanisms for interactive control;
3. Physical representations are perceptually coupled to actively mediate digital representations;
4. Physical state of tangibles embodies key aspects of the digital state of a system. (Ullmer and Ishii 2001)

In 1992, Durrell Bishop's Marble Answering Machine (Crampton-Smith 1995) was an early embodiment of the immediate and playful qualities of tangible user interfaces. The prototype uses marbles to represent messages on an answering machine. A person replays the message by picking up the marble and placing it in an indentation in the machine. Natalie Jerimijenko's Live Wire is a strikingly minimal and whimsically simple demonstration of digital bits transformed into physical atoms. Jeremijenko dangled a plastic wire from a motor attached to the ceiling: the motor accelerates or decelerates based on the amount of traffic across the computer network.

In our previously mentioned research we developed a prototype system known as *ec(h)o*. In this project, simple physical interactives and wooden puzzles at the natural

Figure 1. Components of the Kurio adaptive museum guide.

history museum inspired us. As a result, the user interface for *ec(h)o* was a TUI that coupled a wooden cube with digital navigation and information. In *ec(h)o*, museum visitors held a light wooden cube and were immersed in a soundscape of natural sounds of and information on the artifacts on display (see Figure 2). Visitors navigated the audio options presented to them by rotating the cube in their palm in a direction that corresponded to the spatial location of the audio they were hearing [we will return to this project below but for a detailed account see (Wakkary and Hatala 2007)].

In our experience with TUIs, they bridge the virtuality of the museum guide system and the physical surroundings of the exhibition. As such, the adaptive museum guide first becomes more integral to the physical ecology of the exhibition including artifacts, display systems and architecture rather than being a separate technology. It is important to note that our social interactions are mediated, in large part, by objects and environments as much as they are by direct contact with others (Kaptelinin and Nardi 2006). Awareness of context is critical to sociality. Secondly, with TUIs, our understanding of interacting with technology is informed by our rich experience with physical artifacts and surroundings – because we can leverage existing embodied and cognitive understanding. Analytically, Kenneth P. Fishkin (2004) provides a taxonomy that allowed us to explore these two factors further. Fishkin's taxonomy is a two-dimensional space across the axes of *embodiment* and *metaphor*. Embodiment characterizes the degree to which 'the state of computation' is perceived to be in or near the tangible object. As we discussed, it expresses the integration of computation with the physical artifact and environment, Fishkin details four levels of embodiment:

1. *Distant* – representing the computer effect is distant to the tangible object;
2. *Environmental* – representing the computer effect is in the environment surrounding the user;
3. *Nearby* – representing the computer effect as being proximate to the object; and
4. *Full* – representing the computer effect is within the object.

Along the second axis, Fishkin uses metaphor to depict the degree to which the system response to user's action is analogous to the real-world response of similar actions – the existing embodied and cognitive mappings. Fishkin divides metaphor into *noun metaphors*,

Figure 2. The tangible-user interface of *ec(h)o*.

referring to the shape of the object, and *verb metaphors*, referring to the motion of an object. Metaphor has five levels:

1. *None* – representing an abstract relation between the device and response;
2. *Noun* – representing morphological likeness to a real-world response;
3. *Verb* – representing an analogous action to a real-world response;
4. *Noun + verb* – representing the combination of the two previous levels; and
5. *Full* – representing an intrinsic connection between real-world response and the object which requires no metaphorical relationship.

In Figure 3, we have applied Fishkin's taxonomy to *ec(h)o*. *Embodiment* would be considered 'environmental' bevause the computational state would be perceived as surrounding the visitor, given the spatialized audio display output. With regard to *metaphor*, the *ec(h)o* TUI would be a 'noun and verb' as the wooden cube is reminiscent of the wooden building blocks and the motion of the cube determine the spatiality of the audio – as turning left, in the real world, would allow the person to hear on the left. If we consider the visitor's movement, the embodiment factor would still be environmental and we would have to consider the visitor's body as being 'full' in Fishkin's use of metaphor. So in representing the entire system, we plotted *ec(h)o* between 'noun + verb' and 'full' on the metaphor axis.

It is natural to think that optimal TUIs would be 'full' in both *embodiment* and *metaphor* dimensions, and Fishkin suggests as much. However, we caution that in the case of museum guides and, in particular, when considering the sociality of museum visits, *embodiment* is between people, technology and the environment. Accordingly, TUIs in museums are optimal when computation is perceived to be *environmental* and *nearby* rather than solely within the device.

In summary, we believe tangibility is critical in considering the social dimensions of museum visits in museum guides. TUIs can integrate the computational and physical affordances of the museum visit experience, and visitors can leverage embodied and cognitive models of interaction in incorporating new technology. Visitors benefit from augmentation of computation yet maintain awareness and embodied connection to their surroundings, which ultimately supports social interaction.

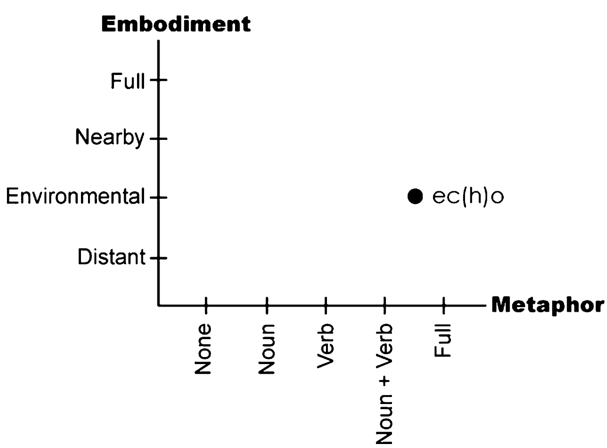

Figure 3. *ec(h)o* plotted in Fishkin's TUI taxonomy.

Situating interactivity in museums

Interactivity can be understood in many ways. We focused on individual or group experiences in museum visits and models of content delivery. In this section, we review a range of systems from the last decade with a particular eye on how these past approaches provide insights into designing for families in which sociality and group activity are paramount. In reviewing the various systems, we have developed a matrix that compares the visit type (individual/group) to visit flow (information delivery/game-interaction) which aims to uncover the major factors that affected the design of the various systems.

In visit types, we refer to *individual* as systems that target interaction with single individuals, whereas *group* refers to interaction models aimed at groups of individuals. *Information delivery* refers to the approach of an information corpus or repository that is presented to the visitor, whether adaptively or by user selection. Providing the visitor with the ability to interact with the exhibit content in a playful manner we have referred to as *game-interaction*. Often the *game-interaction* approach will use games as a means to educate the visitor, as opposed to providing information about an artifact. By employing a cross-matrix of both types of categorizations, it becomes possible to understand how both past and current museum guides mediate the museum experience.

Many of the systems we reviewed were *information delivery* in style, while also falling under the *individual* category. Typically they involved a PDA and an audio/visual interface such as the Blanton iTour (Manning and Sims 2004). Among the first of such guides was the *HyperAudio* project (Petrelli and Not 2005), which used an adaptive model that we will discuss again in the next section. In the *HyperAudio* system, individual visitors were encouraged to walk about the exhibition with the handheld device and headphones, stopping at various exhibits to learn more about specific artifacts in their surrounding. As noted by Petrelli and Not, 'the presentation (audio message and hypermedia page) would be adapted to each individual user, taking into account not only their interaction with the system, but also the broad interaction context, including the physical space, the visit so far, the interaction history, and the presented narration' (Petrelli and Not 2005). The presentation that is displayed also provides a link that the participant can click on with a palmtop pen to gather further information about the artifact of interest. By so doing, the visitor is provided a map of the museum on which the location of the new artifact is displayed, to allow the visitor to see the artifact in person if he desires. The authors also describe their interest in keeping the graphical user interface to a minimum so as not to distract the visitor. It is for this reason that audio is chosen as the main channel of information delivery.

The *PEACH* project (Stock et al. 2007) provides the visitor with a digital character on their PDA that provides information on various artifacts within the exhibition. The *PEACH* guide also contains rich media in the form of video close-ups of frescoes and detailed descriptions of paintings. Unique to this system is the availability of a printout, which provides the visitor with an overview of the exhibits he encountered while at the museum.

We have observed, in a commercial system developed by a member of our team as part of Ubiquity Interactive known as VUEguide, that rich media images can at times become more engaging than the authentic object on display. We believe the virtual image can be integrated easily into a narrative world of information delivery. For example, interactive images of Bill Reid's 'Raven and the First Men' sculpture engaged visitors deeply with the screen and encouraged a 'back and forth' exploration between the actual and the virtual (see Figure 4).

Figure 4. Interactive image of a Haida sculpture that visitors found engaging in the VUEguide system.

Berkovich et al. (2003) developed the *Discovery Point* prototype, a four-button device that delivers audio to the museum visitor. The device allows the visitor to listen to short audio clips about artifacts that are controlled by the visitor. The visitor can also create a virtual souvenir by pressing the 'MailHome' button, which adds the artifact in question to their personal website created upon entering the museum. The device functions without the use of headphones. Instead, audio is delivered through specialized speakers which direct audio to a precise area around the artifact, so as not to disturb other museum visitors.

The *Sotto Voce* system, produced by Aoki et al. (2002) provided the first instance where researchers focused on group activity. The system contained an audio sharing application called *eavesdropping* that allowed paired visitors to share audio information with each other while on an information delivery tour. In designing the application with three main factors in mind (the information source, the visitor's companion and the museum space), the authors remarked that the system showed that the visitors used the system in creative ways, and with social purpose, while presenting the opportunity for co-present interaction.

In recent years, research has continued on group-based museum tours as an area of interest. Additionally, orientation has shifted from information delivery tours to *game-interaction* activities. This is evident in the *CoCicero* project implemented in the Marble Museum in Carrera, Italy (Laurillau and Paternò 2004). The *CoCicero* prototype focused on four types of group activities; (i) *shared listening* – similar to the *Sotto Voce* system; (ii) *independent use* – to allow individuals to choose not to engage in group-based tours; (iii) *following* – to allow an individual to lead other members of a group; and (iv) *checking in* – which allows members in a group to know how others are doing through voice communication while not being physically present. The authors state that communication, localization, orientation and mutual observation are four elements that are key to a collaborative visit. The guide functions by providing museum groups a series of games, such as a puzzle and multiple-choice questions, which require the visitors to gather clues through viewing the exhibits within the museum.

Similarly, the *ARCHIE* project (Loon et al. 2007) has developed a learning game for school children that allows visitors to trade museum-specific information to gain points in order to win a game. With each player having a specific role that he plays, the visitor must understand various levels of information gained from exploring the museum in order to improve his score. Although the *ARCHIE* project is only in its prototype stage, it is clear from their initial findings that the *game-interaction* approach does foster user interest in museum content. Our own system, *ec(h)o*, is unique in relation to other systems. It is exclusively an individual type system (which we now see as a significant drawback) yet it used a *game-interaction* approach. Our interface aimed for an interaction based on an open-ended game qualities or what we referred to as play. The play took on two forms: (1) *content play* in the delivery of information in the form of puns and riddles; and (2) *physical play* that consisted of holding, touching and moving through a space: simple playful action along the lines of toying with a wooden cube.

In summary, it is evident that the majority of research and development has been in the area of *information delivery* and *individual* visit types; see Figure 5, where we plotted the different systems we reviewed. *Sotto Voce* is among the first to explore co-visiting or group interaction with a museum guide within an information delivery context. Group interaction is a new area and chronologically represents a trend, especially when combined with a *game-interaction* approach.

Situating adaptivity in museums

This section surveys those projects that deployed user modeling. User modeling is the use of artificial intelligence software techniques to construct conceptual models for users that enable predictions and responsiveness to user interactions. The projects we review include: *Hippie*, the *Museum Wearable*, *ec(h)o* and *HyperAudio*. We have also analyzed a system that is currently web-based, known as *CHIP*. Each system offers the museum visitor some form of personalized content such as audio or video clips, text and images, and each uses aspects of visitor interaction with the system to achieve customization. The details of each project are discussed first, where we provided a detailed account of each project's approach to adaptivity. The overview will be followed by an analytical discussion that includes a cross-matrix used to frame the current research in the field.

Earlier we introduced the *HyperAudio* system from 1999 (Petrelli and Not 2005). Audio content generation was based on a *visit model* that looked at the grouping each user was in, whether it was a first or repeat visit, how long they planned to stay and what kind of interaction type they preferred. Underlying the model was a simple Boolean variable indicating interest in each item, based on whether the user remained in front of an object after the relevant presentation finished or whether they turned off the presentation.

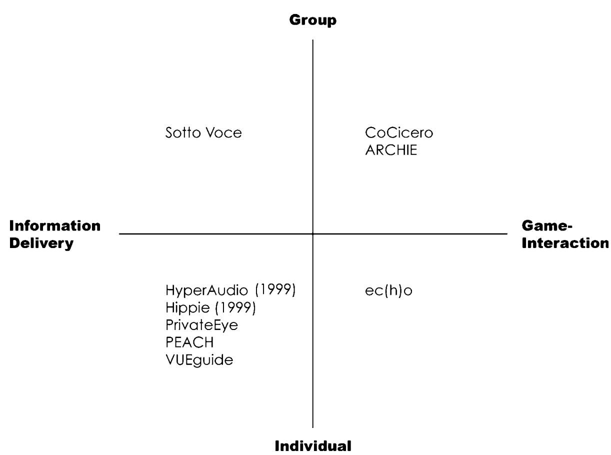

Figure 5. Cross-matrix of visit flow and visit type.

Another early attempt to develop a context-sensitive, adaptive museum guide was the *Hippie* project (Oppermann and Specht 1999, 2000). *Hippie* contained models for three distinct components: (1) a static domain model (objects to be presented and processed about), (2) a static space model (physical space) and (3) a dynamic user model. In constructing the user model, the authors assumed that visitors had a 'stable interest trait structure', but that environmental and contextual factors played a role in the actual activation of that structure at any given moment. The goal of their user model was 'to predict the information needs of a user in a given episode of a visit'; thus the model made inferences regarding the next exhibit to visit and the next piece of information to present. Interest in particular exhibits was inferred by time spent there as well as the number of information items selected. They also suggest using 'differentiated navigation behavior' to indicate interest, i.e. viewing artworks from multiple locations rather than only one indicates more interest. Content was classified according to type, and used to infer what kind of information the visitor was interested in. The HIPS project also applied Veron and Levasseur's 1999 ethnography work in museums, which identified four physical movement patterns of visitors: ant, butterfly, fish, grasshopper (Marti et al. 1999).

1. Ants proceed methodically through the entire museum space, looking at everything;
2. Butterflies fly around from work to work based on interest level;
3. Fish swim through the space quickly, glancing at things in a cursory fashion; and
4. Grasshoppers also bounce around, but with less of a defined idea of what they are interested in.

Visitor type and information preference was proposed as a way to assemble appropriate length audio clips for each individual.

While the *Hippie* system asked the users what areas they wish to explore, other approaches did not give this level of control to the user, such as the *Museum Wearable*, which assembles and delivers personalized content to the user without explicit user interaction (Sparacino 2002). A Bayesian network is used for user classification and decisions about content assembly. Sparacino uses a ternary classification of visitors as busy (cruise through everything quickly), selective (skip some things, spend long on others) and greedy (spend a long time on everything). Data were collected and used to set prior probabilities of a model based on path and pause duration patterns. Upon approaching a new exhibit, a sequence of content clips was assembled dynamically using user type to determine how long it should be.

Th *ec(h)o* project provided visitors with a choice of audio clips throughout their museum visit (Hatala and Wakkary 2005). The *ec(h)o* user model captured two basic kinds of information about the museum visitor using the guide: interaction history and user behavior information. Interaction history recorded movement through the museum space along with the sound objects selected for listening, whereas user behavior information kept track of the user's interests. Interest was set by the user's explicit choice from a number of different concepts at the beginning of the museum tour and then updated based on the exhibits they paused at during their exploration of the museum space and the choices they made regarding which audio content to listen to. If the user showed special interest in a specific concept or two, those concepts would become highly weighted in the model and content related to them would be offered frequently. However, to avoid the complete stereotyping of a visitor, a 'variety' element was also included in the recommendation algorithm, so there was the possibility of sound objects being offered that would allow the user to move away from their heavily weighted interests.

The most recent project to use adaptability in museums is the *CHIP* project, which is currently web-based only. This project allows a user to generate a personal profile via an online rating system for artwork (Aroyo 2007). Images in the system are annotated semantically for artist, period, style, visual content and themes. As users rate them with one to five stars, the user model is refined to reflect their preferences more clearly. The classification ratings (e.g. four stars for Impressionism) are inferred from the explicit work ratings, and can be viewed at any time. If the user disagrees with the system's calculation of the classification rating, they can adjust it manually. The user can also ask to see 'recommended works' which pulls out unrated artwork that the model believes the user would rate highly (four to five stars). Users can query as to why the system recommended this work, and will be provided with the individual classification ratings that underlie the suggestion. The next step in the project is to integrate this with technology in the physical museum, so that users can access their profile in the exhibit.

The *PEACH* project also allows the user to participate actively in the construction of her user-model through a widget (Stock et al. 2007). The 'like-o-meter' widget allows the visitor of the system to state whether she likes or dislikes a given museum artifact, which affects the amount of information the system provides for subsequent related artifacts. The authors suggest that their widget was clearly understood and enjoyed by visitors.

Our aim here is to determine what is common practice in user-modeling, what is more uncommon and experimental and what has not yet been attempted. One of the first aspects to consider is what kind of data the systems gather and use as input to the model. There are two basic categories of input commonly used: physical data and content-based data. Physical data include such things as knowledge of the visitor's current location (*Hippie*, *Museum Wearable*, *ec(h)o* and *HyperAudio*), of their overall path through the museum space (*Hippie*, *Museum Wearable*), and of their stop duration at each specific exhibit (*Hippie*, *Museum Wearable*, *HyperAudio*). Content-based information includes knowledge of what content the visitors have listened to or selected (*Hippie*, *Museum Wearable*, *ec(h)o*, *CHIP*, *HyperAudio*) and how they rate that content (*CHIP*, *PEACH*). From this basic input, all the systems extrapolate and make inferences about categories into which the user falls or characteristics the user might have, based on the observed behavior. Every system infers user interest in an artifact/exhibit, based usually on their movement towards it, presence near it or selection of it in some way. The systems all have the capacity to detect user interest in broader themes or topics, as signaled by the selection of multiple items, which have been annotated similarly. Some of the systems also include the ability to detect interest in a specific information type, as signaled by selection of specific kinds of content (the *Museum Wearable*, *Hippie* and *HyperAudio*). For example, a user might ask repeatedly for artist biography content, or for details on how an artifact was constructed. The final type of inference found in these systems is the classification of visitors as a certain 'user type'. This includes the fish/ant/butterfly/grasshopper path classification from the *Hippie* project and the greedy/busy/selective user type from the *Museum Wearable*, both of which used movement patterns to sort users.

One important distinction among the ways the projects handle system input is the degree of control that the user has over the cues that the system is picking up on. Another way to think about this would be in terms of the opacity level present in the interaction. With some of the systems, it is easy for users to tell what kinds of information the system is picking up on, such as their presence next to an object or their deliberate selections within the system; we describe this approach as *transparent interaction*. Other systems have much more opaque interactions that are being picked up on, such as the path through the space or their patterns of stop duration and movement. In these cases, the user of the system may never guess that such elements are being used as input for the user model, and thus it is beyond their control to affect what the system is doing in response to them; we describe this approach as *opaque interaction*. It is possible that this opacity will yield a more fluid, intuitive interaction with the system, but it is equally possible that it could result in a frustrating experience where the user does not understand why the system is responding the way it is.

With the collected and inferred data as input, the next concern is what the system presents back to the visitor as output. Several of the guides offer a set of further audio and/or video content that the user can select from (*Hippie*, *ec(h)o*). The *Museum Wearable* also presents audio/video content, but does not allow the user to select what they view; instead, the model automatically assembles a tailored presentation for the user. *HyperAudio* combines these approaches by assembling a tailor-made audio presentation and also allowing for individual exploration of topics via the handheld device. A third option for output is to generate recommendations of other pieces the visitor might like based on the model's understanding of the visitor (*CHIP*). There is a distinction here between systems that have *static content* and those which have *personalized content*. The *Museum Wearable* and *HyperAudio* actually tailor the content itself to the individual user. In the other systems, the content remains the same, but the order in which it is presented or the options available at any moment are tailored to the individual user.

In summary, Figure 6 shows a cross-matrix of this *static–personalized content* dimension with the *opaque–transparent interaction* dimension. As can be seen from the diagram, the majority of research thus far with user modeling in museum applications has involved static content and transparent interaction. There have been a couple of different ways in which the input/inference data affects the output. All the guides have the simple correlation of high user interest leading to more content related to that user interest. *Hippie* and the *Museum Wearable* also use user-type classifications to affect the duration of the content offered to the user. Room still exists for a range of creative thinking in this area, especially with regard to how collected data can influence the system interaction and output.

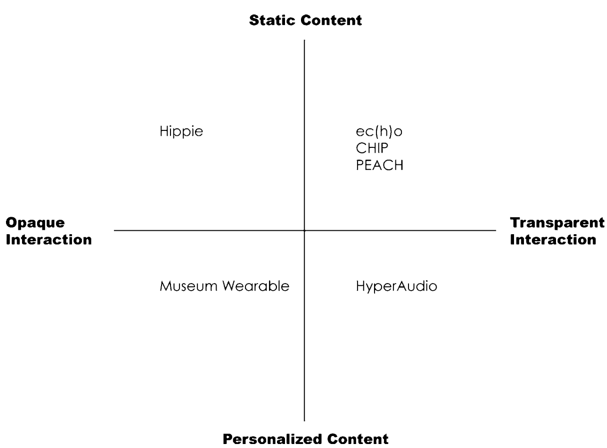

Figure 6. Cross-matrix of interaction and content types.

Discussion

Through gathering research in this study, it is possible to understand the variety of approaches taken to augment the museum space. When faced with group-based activities, the PDA may further distract the visitor from his/her companions. The group-based applications discussed in this study revealed a shift towards a *game-interaction* approach – while all used PDA devices to guide the visitors through the museum. Again, we believe TUIs may have a greater role and affect in this regard. Research within group-based tour applications is fairly limited, and has become the focus of two newer studies (*CoCicero* and *ARCHIE*). The *game-interaction* approach seems not only to affect the way in which individuals browse through the museum, but may also affect the manner in which learning occurs. The *game-interaction* approaches discussed here encourage the visitors to find artifacts which match specific criteria in a quest-like fashion. This type of activity might be useful in teaching visitors what singular artifacts are, but may inhibit the communication of the contextual significance that often surrounds artifacts in museums. The earliest of systems to adopt a group-based approach, *Sotto V*oce, note that co-present interactions should be supported. The *CoCicero* project takes the concept further by introducing other group-based behaviours to be supported, such as *following* and *checking-in*. As our focus is on group-based interaction, using the findings of such projects may prove helpful in designing an application that fosters group visits by families to museums, such as our own *Kurio* project (see Background section).

With regard to a user-modeling approach, the majority of the research lies within supporting *transparent interaction* and *static content*, although it is difficult to state whether one method is superior to another at this time. It could be argued that a push towards even more transparent input is desirable. The *CHIP* project is the most *transparent* of all the interactions, allowing the visitor to adjust the user model manually and gain feedback from the system as to why certain recommendations have been made for them. No such hybrid adaptive and adaptable system has been implemented within the user space itself. Alternatively, it could be fruitful to explore the area on the extreme other side of the *transparent–opaque interaction* continuum, by creating a system where users are unable or unlikely to guess what aspects of their behavior are being used within the system. If conducted properly this could yield a very immersive, fluid-feeling interaction. Projects that have attempted to classify visiting patterns have done so within the individual-based tour context, and there is a lack of research on museum visitor patterns for groups – a potential area of interest for us to address.

There is also little research on adapting to the group conditions of the visitor, e.g. taking into consideration the fact that person A is a mother visiting with three children, while person B is a senior citizen visiting with friends. Modeling users on the level of group dynamics is a new and growing area within user modeling, one that we have explored (Wakkary et al. 2005) and hope to bring to the museum domain. In terms of content, there is definitely space to explore in the realm of adaptive content – taking the personalization of the museum beyond simple recommendations and on-demand information access and moving it into the realm of individualized presentations.

We began the paper with a discussion on tangibility as a mediating bridge between computation and context that militates the lack of support for social interaction. Tangibility may preclude some of the directions in user modeling, such as *transparent interaction* of systems such as *CHIP*, which is web-based after all. However, tangibility could be seen as an enabler in *game-interaction* approaches and *group* interaction, given its relative playfulness in comparison to graphical interfaces, the ease of sharing tangible devices and the leveraging of past patterns of social interactions mediated by objects.

Future trajectories in the research of interactive museum guides

It is inherently risky to predict what may develop in the future. Given the analysis in this paper, however, there is evidence for the following future trajectories resulting from a balance of assessed needs of a museum visit and the capacity to design and implement technology in the case of interactive museum guides.

Embodied interaction

As discussed previously, embodied interaction is a computing paradigm in which tangible computing and social computing become intertwined and incorporated into our everyday environment and activities (Dourish 2001). This notion fits the majority of museum settings very well, given the sociality of museums and the reliance on curious and playful interaction with physical objects and interactives. An additional contributing factor to the fit with most museums may be a heightened awareness on the part of visitors of the physicality of things due to the presence of remarkable artifacts on display. We discussed how, in *ec(h)o,* tangibility afforded a greater awareness of the surroundings of the museum, as visitors were not distracted by a handheld visual display and visitors' actions were perceived to be part of typical interaction with the environment through actions such as walking and gesturing. A goal within this trajectory of research will be to bring tangibility qualities together with the social computing aspects of works such as *Sotto Voce* and *CoCicero,* in which displays, communication and activities are shared through PDAs. Wireless technology underlies the advent of interactive museum guides and, while the networking capabilities were utilized initially for distribution of information, there is the needed shift to social communication and coordination, not unlike the current online social networking.

Gameplay

Gameplay refers to the quality of the mechanics or play in a game. We observed that the idea of gameplay can be applied to interaction with museum guides, often in the service of learning. Games and play are used in the museum as an interaction convention that is a general set of expectations that people accept for a museum visit as a means of exploring and learning about the exhibition. Gameplay, or game interaction, can be used as a more entertaining way to deliver information but we observed in *ec(h)o*, Co-Cicero and *ARCHIE* that gameplay supports learning in ways that are equally about constructivist exploration and discovery. Additionally, the latter two utilized games as a coordinating and collaboration function for families and groups.

Transparent or opaque interaction

In our discussion of user models and adaptivity, we made the important distinction between transparent and opaque interaction. Transparent interaction occurs if it is understandable to a visitor how their actions and interface interactions influence the user model, as in the case of user ratings, selection of content or navigation options or explicit request of user preferences. Opaque interactions occur when visitor actions inform the user model in ways that are not apparent to the user, such as movement through the exhibit, duration of pauses and gaze tracking. The degrees of transparency in collection of user model data directly affect the quality and nature of the visitor experience. In our view, there are almost equal trade-offs in either direction, as we discussed, and research will probably continue on both fronts. A probable practical outcome, and current practice in some cases, is the combination of both approaches within a single system.

Personal digital assistants, graphical user interfaces and hybrid systems

Past interactive museum guides adopted a mobile computing approach utilizing graphical user interfaces (GUI) on hand-held PDAs as the device and interface modality. Traditionally, the PDA/GUI method has served the information rich experiences well. We believe, however, that the trends we have been discussing may alter this approach. First, the emergence of tangibility offers an approach different from mobile computing. The user interface demands can be distributed across different tangible devices that are each simpler (without a GUI), can be designed to work together and are customized to the particular setting and activity. We believe tangibility to be a group-centric approach with more reliance on context than mobile computing which, to date, has been individual-centric and virtual over contextual. We believe that this emergent tangibility model will support group and family interaction more effectively in museums. Having said that, the trends of group and game interaction require coordination and collaboration. Here, a PDA or shared display with a GUI can serve a key role in coordinating different members of the group and family during a museum visit. Additionally, a GUI provides a virtual collaborative space that in game interaction can represent the shared state of the *game* as it and provide a collaborative space to communicate and help each other.[1] Hence, we see a shift in the use of PDA/GUIs from information delivery to providing shared virtual space for coordination and collaboration. Considering all this, we came to the conclusion that hybrid systems best support the type of embodied interaction of tangible and social computing that we have been discussing. A hybrid system might included tangible devices and shared displays in the form of a PDA and or tabletop computer. This is exactly the approach we have taken in *Kurio*, which we discussed briefly earlier (see Background section and Figure 1).

Benefits of re-situating interactive museum guides

Many research and technology areas evolve and change in waves and we believe that interactive museum guides are no different. Further, for this paper we aimed to illustrate fundamental shifts in re-thinking interactive museum guides to address tangibility, interactivity and adaptivity. This re-situating of interactive museum guides holds benefits for museum administrators considering interactive technologies for their museum, or researchers and developers looking anew or again at the interactive museum guide domain:

- *Closing the social gap.* In our analysis there is a growing interest in families and groups, which begin to address the gap that in reality families and groups make up the majority of museum visitors while in the past interactive museum guides have been designed for individuals.
- *Naturalizing technology.* Technology in the museum adapts to the everyday environment of the museum, such as physical interactives, exhibit displays and artifacts in the proposed shift to tangibility. As Ishii suggests, it is time for technology to 'rejoin the richness of the physical world' (Ishii and Ullmer 1997),

which allows us to consider the larger design problem of the whole museum experience rather than focusing on the novelty of new technology.

- *Shift to exploration and discovery.* Interactive museum guides in the past focused on information access and richness. The move towards embodied interaction and game interactions creates the opportunity to design learning activities with interactive technology that are based on personal exploration and discovery, rather than information retrieval and retention.

Conclusion

As shown in this paper, there are currently several approaches for adaptive museum guides under exploration. Through analyzing current contributions through the three key areas of interest – tangibility, interactivity, adaptivity – we were able to develop a comprehensive outline that provides a theoretical grounding for our future research in a family and social-based museum guide. The majority of the current literature focuses on the interactions of a single visitor, but through analyzing trends in the museum guide research, the focus appears to be shifting. We discussed four interrelated trajectories for interactive museum guide research including: embodied interaction, gameplay, transparent and opaque interaction and the new role of PDA/GUIs. We concluded with the benefits of the shifts in research and practice, including addressing the presence of family and group visitors, integrating technology in a museum setting more effectively and opportunities for designing learning activities based on exploration and discovery.

Note

1. In discussing PDAs, further consideration should be given to impact of the changes in industry and use of smartphones. The growing prevalence and comfort with smartphones will have an impact on the role PDAs in museums; in particular, visitors will have expectations of using their own mobile devices through downloadable software or online applications.

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