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One Butterfly: Understanding Interface and Interaction Design for Multitouch Environments in Museum Contexts

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One Butterfly: Understanding Interface and Interaction Design for Multitouch Environments in Museum Contexts

by

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Preface

The Smithsonian Institution, a traditional leader in the popularization of art in America and beyond, has a stake in bridging the digital divide in order to stay relevant in a "bits filled" world. It is imperative that the Smithsonian create cost-effective, in-house information features to highlight the important work that each unit produces to bring added value to the Smithsonian's diverse patrons, visitors, scholars, children, families, adults and seniors. The hope is that this will, over time, increase both the appreciation and support of the Smithsonian Institute.

This report, predicated on an interest in helping the public better connect with museums by the use of digital technologies, is an effort to change the typical construct that has for centuries defined this interaction. The purpose underlying this effort is to improve access to museum materials by establishing more fruitful connections with the public through technological innovation. The paper posits an argument for the use of multitouch hardware and natural user interfaces in museum computing contexts as a means of enhancing interactions between people and museum collections.

This report culminates a year-long research project exploring user interface and interaction design topics in multitouch computing environments for use in museum contexts. Each of these topics, as well as their interfaces, are areas of continuing research interest. The future of the One Butterfly project, limitations of the design, potential avenues for evaluation as well as this project's relationship to current and future research are discussed. With continued pursuit of knowledge in these areas, the underlying interests motivating the One Butterfly project will ultimately be served.

The One Butterfly project grew out of my personal interest in the arts. Though institutions are building and refining their web presence, they have yet to overcome the physical and technological barriers that separate the collections from the public. Right now, the best way to take in the wealth of interaction that cultural objects provide is to visit a exhibit museum—but what role does technology have in expanding on that experience?

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Abstract

One Butterfly: Understanding Interface and Interaction Design for Multitouch Environments in Museum Contexts

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Museums can be perceived as stuffy and forbidding; web technologies can enable museums to expand access to their collections and counterbalance these perceptions. Museums are searching for new ways to communicate with the public to better make a case for their continued relevance in the digital information age. With the emergence of multitouch computing, other diverse forms of digital access and the popularization of the user experience, challenge museum design professionals to synthesize the information seeking experience that occurs on multiple computing platforms.

As a means of addressing these issues, this Master's Report summarizes the One Butterfly design project. The project's goal was to create a design for a multitouch interface for federated search of Smithsonian collections. This report describes the project's three major phases. First, an idea for an interface was developed and designs

based on that idea were captured and clarified. Second, a formal review of related research was undertaken to ground these designs in the museum informatics, user interface design, and multitouch interaction design literatures. Finally, the report concludes with a review and reflection on the designs and their underlying ideas in light of things learned in the previous phases.

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Introduction

Museums are often perceived as stuffy and forbidding to many. This limits access to collections. Web technologies hold promise for enabling museums to expand access to their materials and collections and perhaps counterbalance public perceptions of their forbidding nature. While the design of effective website interfaces has been a topic of study for many years, museums are increasingly expected to offer much more in terms of innovative approaches to improving access issues. In response, museums continue to look for better ways to communicate with the public.

Employing improved on-location interactive technologies is one way museums can productively make a case for their continued relevance. Large-format multitouch and mobile computing environments herald an emerging convergence of computing platforms. This phenomenon becomes more prominent as ownership of computing devices steadily increases. Museums, like other public information spaces, will soon be expected to address the convergence of computing environments in an increasingly ubiquitous computing culture. The One Butterfly project represents an initial approach to address this convergence of mobile, personal, and public computing experiences.

The initial goal of One Butterfly was to design a suite of multitouch interfaces for a federated search of the Smithsonian collections. This report describes the Smithsonian's approach to information technology, as well as presents a formal review of related research. To synthesize the themes identified in the reviewed literature, a discussion follows the presentation of the initial designs created for One Butterfly. A discussion about the future One Butterfly project concludes this report.

Early Work: Understanding the Smithsonian

The One Butterfly project began as a supervised individual study during the fall semester of 2008. The project was based on a federated search initiative at the Smithsonian Institution. The project's development can be summarized in three phases. First, an idea for a suite of interfaces was developed and designs based on that idea were captured and clarified. Second, a formal review of related research was undertaken to ground these designs in museum informatics, user interface design, and multitouch interaction design literatures. Finally, a stage of review and reflection on the designs and their underlying ideas in light of things learned in the previous phases was completed.

The following sections discuss how web initiatives and technology policies in general have been handled at this institution. Following a literature review, further discussion of the One Butterfly project include a description of the design opportunities presented, in light of this review, by the Smithsonian Institution's Collections Search Center.

THE SMITHSONIAN INSTITUTION

The Smithsonian stores, conserves, preserves, displays, and holds a vast collection of objects, artworks and specimens. The institution began in 1846 when James Smithsonian, a British scientist, stipulated in his will that all his wealth was to be donated to the United States under the name the Smithsonian Institution, "an Establishment for the increase & diffusion of knowledge" (Smithsonian: Mission, n.d.). The Institution, since then, has been governed by an appointed secretary who reports directly to Congress. The first secretary, Joseph Henry, quickly turned the Smithsonian into a leading research center for science in the United States. The Smithsonian continued to grow and the scope of the institution broadened to include arts and culture (Smithsonian: History, n.d.).

The Smithsonian Institution is now the largest museum complex in the world and offers numerous programs and services. The central purpose for its services and programs is to provide access to and information about the one hundred thirty-six million items under its care. The complex organizational structure of the Smithsonian is often unappreciated. It is comprised of nineteen museums, one hundred and fifty-six affiliate museums, and nine research centers. The Smithsonian holds eighty-nine thousand cubic feet of archival materials and one and one half million library holdings for the citizens of the United States (Fact Sheet on the Smithsonian's Collections, 2008).

Information Technology at the Smithsonian

Like other organizations, the Smithsonian's dependence on technology has increased dramatically since the institution's founding. As always, change in an organization of this size is slow and difficult. Many offices and committees are required to develop strategic plans for information technology for this vast and disparate organization. Administratively, the Smithsonian Information Technology (IT) is complex, consisting of multiple hierarchies of authority. Because it is such a large institution, the Smithsonian organizes itself vertically from the top down. There are three important levels that separate IT management; listed hierarchically these are: the Office of the Chief Information Officer (OCIO), the Smithsonian Institution Research Information System (SIRIS), and unit IT departments.

The OCIO is the Smithsonian's information technology governing body. This office "plans and directs the development, implementation, maintenance, enhancement, and operation of the Smithsonian Institution's information technology (IT) systems"

(Smithsonian: Office of the Chief Information Officer, n.d.). The SIRIS office works with several Smithsonian units. The SIRIS office uses an IT system by the same name, 'SIRIS,' to store records from across the Smithsonian. This system was created to pool and share data throughout the Smithsonian organization. This system is closely related to the federated search system upon which the One Butterfly suite of interfaces is based. A yearly strategic planning document describes the SIRIS system in the following manner:

> The Smithsonian Institution Research Information System (SIRIS) is a shared, online, pan-Institutional application that advances Institutional outreach by supporting the management of and access to holdings of twenty Smithsonian libraries, fourteen archives and other specialized databases. SIRIS provides access to […] text records with hyperlinks to images, video and sound files, electronic journals and websites that hold information related to Smithsonian manuscripts, books, journals, diaries, sculptures, paintings, photographs, objects, film, video, maps, and research data. (Edson, n.d.)

IT departments within each unit are responsible for managing the day-to-day information technology programs, which is no small task. For example, in recent years one of the small archival units, the American Art Archive (AAA), received a five million dollar digitization grant. Beyond just digitization, the grant emphasized access to the archive's most significant collections. Using only intra-unit resources, the AAA set out to create a database-driven website for the display of their collections (Terra Foundation for American Art Digitization Project, n.d.). However, the records and digitized collections produced by the AAA are not available pan-institutionally and hence the Smithsonian has yet to fully enjoy the benefits of these collections that are now processed, digitized, and cataloged.

It is the OCIO's objective to facilitate pan-institutional access to individual unit records. In calling for a centralized data repository, OCIO's strategic plan includes hopeful language regarding development of system inter-interoperability with an emphasis on data sharing. Although, SIRIS's original purpose was information sharing and pooling, units are currently not required to contribute records, even though the SIRIS system was originally introduced as a centralized solution for storage and management of records. This is due largely to incompatibility between existent IT solutions employed. To address this, the OCIO introduced the Collection Search Center initiative. "In [fiscal year] 2007, users conducted over nine million searches on SIRIS databases and the Smithsonian implemented an open source application to provide enhanced searching functionality that bridges the multiple SIRIS databases" (News, n.d.). This initiative signaled a shift in approach to information access and presentation by the leadership.

A Vision for the Future

In advocating for an "enterprise-level mission support systems," the OCIO wants the Smithsonian to be able "to transform and remix its collections and research data in ways yet to be imagined and to provide the necessary tools to search and explore this vast repository of knowledge." The report continues with a description of the new role that websites within the Smithsonian's mission offers to access their holdings.

> The primary vehicle for dissemination of this new wealth of knowledge will be the World Wide Web because it reaches beyond the physical limitations of buildings and other organizational infrastructure. In welcoming millions of visitors of varying ages, learning styles, first languages, and cultural backgrounds, the web will form a conduit for public outreach and research exploration to delight, educate, stimulate, and allow each visitor to experience collections and research in ways that are meaningful to them. (Smithsonian Institution Information Technology Plan Strategic Overview, 2009)

In some ways the Smithsonian has embraced the digital information age and the techno-social implications posed for the Institution and its visitors. While there continue to be significant barriers such as funding reductions to fulfilling the Smithsonian's goal of broadening its digital footprint, several initiatives developed by the Smithsonian demonstrate progress towards the implementation of their approach. Two of these initiatives are described in detail in the Smithsonian 2.0 initiative and the Collection Search Center. These initiatives will be an important part of how the Smithsonian eventually addresses ubiquitous computing.

The Collection Search Center

SIRIS has directed the federated search initiative on which the One Butterfly project is based. In August 2007, millions of records were indexed to the CSC catalog. The stated goal for CSC is to provide a single place to search and retrieve records. The SIRIS office described the CSC in the following way:

> [SIRIS] implemented the first deployment of a revolutionary new online catalog that allows users to search across 1.7 million of the Institution's library, archive, and research holdings. Using the latest indexing technology, the new SIRIS [CSC] system provides an easy 'one-stop' approach to searching these records. The rich content, combined with fast and flexible searching capabilities, make this new catalog a marvelously useful research tool and allows users to browse and select information quickly, providing real-time, automatic connections to related terms. (Center for American Art Research, 2007)

System Description

The CSC system operates in the following way: a user enters keywords or a phrase and the system returns small thumbnails along side the object's metadata relating to the item. This information is a transformation of Machine Readable Cataloging (MARC) metadata records extracted from numerous databases and mapped to a common data format. The MARC records then are ingested by the Lucene indexer. Lucene is a free and open source information retrieval library and is described by SIRIS as indexing software that supports the retrieval of records using Solr, an enterprise open source search server developed in a subsidiary project of Lucene.

The information displayed is both bibliographic and text centric. If one enters a keyword, CSC will return search results. As the project progresses, other data sources with different file formats will be ingested and indexed. In choosing a search solution for CSC, an important functional requirement for the Lucene indexer is a capability to perform full text indexing with file format independence and faceted metadata search capabilities. The ranking mechanism, as configured by SIRIS specifically for CSC, is capable of functioning as more than just a tool but potentially could support exploratory search environments, such as the One Butterfly suite of interfaces (News, n.d.).

Pan-Institutional Management of Metadata

Metadata is an important but often overlooked component of federated searching systems. The MARC standard is not an ideal option for a pan-institutional system because of its bibliographic orientation and complexity. Currently, SIRIS is meeting separately with various museums, libraries, and research bodies to discuss mapping to a single set of metadata elements in order to associate records from disparate entities. Some Smithsonian units are more prepared than others to contribute records to the catalog. The AAA unit is one of the best prepared to contribute. In contrast, some units are not using metadata standards to record and describe their holdings. The CSC project has been proposed, for units like the Smithsonian American Art Museum (SAAM), to encourage the adoption of record keeping practices that allow for interoperability and data sharing pan-institutionally. Still, this is a difficult task to achieve given the autonomy of the units. Data sharing is not a commonly held value and practice in many units' policies and operations. For instance, the AAA does not cross-reference any artist whose works are held by SAAM. Likewise, SAAM promotes no explicit connection between an artist's papers and the same artist's work, even though the Smithsonian may hold both. Federated search, although not performing the exact function of cross-referencing, is one way to address the faulty knowledge-management approaches typical for large distributed organizations like the Smithsonian.

Impediments to the Success of the Collection Search Center

The Smithsonian reported almost one hundred and eighty-eight million visits to their website in 2007 (Smithsonian: About the Smithsonian, n.d.). Webmaster Tools, a web analytics product sold by Google, has been tracking visitor statistics since 2007. Previously, the total number of website visitors was calculated inaccurately and reported numbers significantly higher than the actual discrete number of visitors (S. Synder, personal communication, n.d.). This anecdote describes the awkward way the Smithsonian has understood its web presence. Several impediments to the success of the CSC initiative should also be noted, including the lack of inter-operability between systems, the incompatibility of IT solutions, quality issues in the Smithsonian website, funding limitations that have resulted in piecemeal web development and re-visioning and an absence of consistent values for successfully presenting information that supports an intelligently-networked web presence. Little information is accessible about how the Smithsonian manages on-location interactive technologies—information kiosks, digital displays and smart phone applications; a review of the Smithsonian’s approach to web publishing may provide further clues.

The Smithsonian's many offices operate, for the most part, independently of one another and without significant collaboration. Many problems have arisen from this management style. Various Smithsonian offices have in the past chosen and implemented different, often incompatible IT solutions. Some of the IT solutions employed are outdated and are no longer supported by the companies that developed them. Many of the products used are not inter-operable with other key systems. The Smithsonian has largely chosen and implemented freestanding commercial IT solutions that interact poorly, or not-at-all, with other IT programs in use.

The Smithsonian's web presentation is lackluster and grew mostly on an ad hoc basis, further complicating the situation. When browsing different Smithsonian unit websites, one finds many types of interfaces; some deeply linked pages date back to the mid-1990s. This creates numerous problems for branding, visual continuity, usability, and credibility. The units, however, have been slow to address these problems. Many of the earliest websites were designed originally by catalogers, librarians, database managers in conjunction with a unit-commissioned website design firm. Many of these early websites were designed because, to feel up-to-date, unit managers wanted merely to get content "online" as quickly as possible. Often these early websites were difficult to maintain and aged quite poorly. Often units were reticent to retire older web projects, believing that the content was still useful despite visual inconsistencies within the site.

Grants are a common way the units fund their web projects, and grants can be a good incentive for a unit to improve its website. Currently, grants fund many of the digitization projects at the Smithsonian. Many digitization grants require that the resulting digitized collections be available online. This has caused affected units to rush into updating their interface designs. With the push to develop "web 2.0"-branded sites, units are updating sites in a piecemeal fashion. Additionally, budgeting procedures make hiring a design firm, developer, DBA, or Webmaster a cumbersomely difficult process.

Methods of structuring data, concepts of usability and accessibility and an understanding of the importance of information re-use have been conceptually slow to be adopted. Even within units that are leading proponents of digitizing efforts, interface incompatibilities are treated as ancillary. Often there is a lack of promising structures for cross-referencing records within their own unit's records management system, not to mention across related units' systems. Perhaps this indicates the Smithsonian's approach to on-location interactive kiosk and their relationship to other information platforms on which collection records reside.

Success of the Collection Search Center

The success of the CSC and other web initiatives is imperative. The Smithsonian must offer a visually consistent and relevant web experience to maintain credibility with an increasingly sophisticated public. The Smithsonian's Institution's web presence has become more important than ever because web access has now become the primary method by which the Smithsonian communicates with the public. The public has rightfully come to expect more from the Smithsonian: put simply, users expect well-designed, easily accessed and informative sites that make easier the public's exploration of the vast stores of digital information available. Likewise, the public has become accustomed to accessing an array of information resources—pamphlets, kiosks, tours, films and lectures—during visits on location.

The concept of federated searching emerged as different bodies began to regularly create records for electronic retrieval. The ability to retrieve records across systems was a natural outgrowth of that endeavor. The creation of metadata standards played an important role in search systems, especially those systems designed for records of cataloged documents due to their structure. Broadly defined, 'document' in this context applies to museum objects, manuscripts, archival materials, as well as to books (Buckland, 1997).

A unique opportunity exists to unify the institution's diverse holdings by associating the records in an immersive and usable environment that would collect information in a centralized repository. Initiatives such as Smithsonian 2.0 require marked improvements in the information technology systems at the Smithsonian. Among the changes needed at the Smithsonian are the adoption of intuitive collaboration software, development of an in-house interface design team, unification of the institution's web presence, and significant investment in digital initiatives over several years. These changes are necessary for the Smithsonian to maintain its stature amongst the world's great cultural institutions.

Literature Review

Cultural institutions, such as the Smithsonian, are searching for new ways to communicate with the public, in part to make a case for their relevance in this digital information age. Technological advancements have allowed museums to expand access to their collections and begin to counterbalance the somewhat unfair perception among the populace that museums are inaccessible or boring; other cultural organizations—libraries, archives and research facilities—have received similar characterizations. However, the interface and interactions by which users access a collection also colors the user's impressions of an institution. For example, the SIRIS Collection Search Center catalogue is an incredible advancement in access to the Smithsonian's holdings, yet the existing interface leaves much room for improvement (see Figure 1).

Figure 1: An overview of CSC interfaces.

Given the situation at the Smithsonian, and in the museum community more generally, the following literature review was undertaken to ground the ideas espoused in the One Butterfly project in a tradition of museum informatics, as well as user interface design and multitouch interaction design literatures; this review of literature includes both older seminal works and more recent articles on emerging practices and research topics.

Because the literature on multitouch museum interfaces is not extensive, this review was conducted piecewise in three sections. The first section discusses themes found in the museum informatics literature. As is evident from the previous section, successful implementation of innovative technologies depends heavily on the management of the larger information technology infrastructure. Thus issues surrounding technology and information services used in modern museums are explored. The second section is a survey of major ideas in interface design. The third is a summary of multitouch interaction design research for large computing displays.

MUSEUM INFORMATICS

Museums are complex social environments, in which new information technologies have the potential to affect much more than the ways museums manage their collections.

The quotation above is taken from the first chapter dedicated to the topic of museum informatics in the 2003 edition of the *Annual Review of Information Science and Technology*. Museum informatics is defined as the "study of how information science and technology affect the museum environment" (Marty, 2003, p. 268). Literature on museum informatics is varied by museum type, collection, resources and capabilities, as well as by audience (Marty, 2003, p. 260). However, a review of the literature revealed four fundamental challenges associated with museum information and information in museum contexts all of which are evidenced in the Smithsonian's operations. The following is a description of each challenge.

Four Fundamental Challenges of Museum Information

The first and most basic challenge has been the museum information community's struggle to capture and catalogue the uniqueness and value of objects. "The inherent uniqueness of museum artifacts meant that there was and could be no organization equivalent to [...] the Online Computer Library Center (OCLC) to help museums develop shared databases of museum records; each institution had to tackle the task of cataloging its collections individually" (Marty, 2003, p. 264). Museum information is created and understood in object-centric environments. Traditionally, the notion of a museum object as a single, unique human expression has taken form as a combination of physical substances: canvas, metal, wood. That expression is understood to have intrinsic value; there is, at most, only one expression of the true object. Copies of a museum object, i.e., surrogates, are representations of the object but not the object itself. Surrogates benefit researchers and laypeople alike in that the offer increased and sometimes enhanced access to objects. With unique and intrinsically valuable objects at the center of museum professionals' information creation and information behavior, protectionist values and notions of ownership have stymied attempts to create networked museum information resources.

The second challenge is associated with museum object uniqueness. The creation of data and metadata standards as well as data sharing practices has posed a significant challenge to information management in museum contexts. This challenge is seen in several other information contexts, including libraries. However, the notion of museum objects as intrinsically unique has complicated discussions as to what information should be included in museum records. The museum community tends to be less collaborative and cooperative than the library community. The museum community's achievements in establishing data and metadata standards for object description lags far behind progress in this area by the library community, who has been a leader in standardizing and sharing information. This is in part because museums themselves are unique (Marty, 2003, p. 260).

The third challenge, regarding decisions as to how to package museum information, has contributed difficulties to data and metadata standardization and sharing. The process of creating information around a museum object is complex. There are multiple levels of information to maintain (Marty, 2003, p. 262). Records exist to document an object's provenance as well as to provide an interpretation of the object. These records exist in both analog and digital forms. The records themselves have a history that may persist longer than the object itself. Additionally, the objects also have a history that likely began before records of the object existed; that history is fragile and can easily be misinterpreted or destroyed.

The fourth challenge, establishing collaborative and cooperative relationships between museum organizations, has both contributed to and suffered from a lack of solutions to the previous three challenges. Despite this, both collaboration and cooperation are imperative from standpoints both financial and pragmatic. It seems a vicious cycle exists in which individual museums lack the financial, intellectual, and technical resources necessary to address the first three challenges and thus must seek to solve the problem as a community. Unfortunately the first three challenges make it very difficult for museums to engage in collaborative and cooperative activities.

The history of museum informatics is brief. Work done between the 1960s and 1980s established practices for cataloging (i.e., record creation), automated computerization of records (i.e., record conversion), and storage of records in databases. Since the 1990s museums have sought to establish their web identities and digitize their collections. Issues surrounding these topics have dominated museum informatics literature. In addition, the use of on-location interactive technologies such as audio guides, information kiosks, and mobile applications has been a central topic in both practical and theoretical works on museum informatics. Over the last twenty years, museum professionals debated and dealt with the significance of web and interactive technologies with a special focus on the end user experience. If explored in greater detail, the fifty-year history of museum informatics can be expressed as a series of activities addressing those challenges. As the field of museum informatics matured, museums made significant achievements in their work to convert, automate, standardize, digitize, distribute, and share museum information via in a digital information environment. In the case of the Smithsonian, this work supported the development of a federated search system as a new means for accessing museum information. Nonetheless, such achievements invite debate on the benefits and threats to museum information in a digital environment.

Benefits and Threats of a Digital Environment in Museum Contexts

For decades, access to museum information has centered on in-person visitation, printed materials, and face-to-face communication. By visiting a museum, and potentially its library or bookstore, one was able to gather printed materials on the museum's collections. Communication with museum professionals, from docent to curator, required attending museum events such as gallery talks, lectures or film screenings. In contrast, digital environments offer alternative and complimentary ways for accessing museum information. The virtually unlimited storage capacity of digital environments allows museums to create new content without the strictures of physical storage. Museums have embraced this opportunity; they have created new information resources using video, audio and digital surrogates of museum objects. Related to notions in the literature of the "museum without walls" and the idea of turning "museums inside out," museums have created videos to present art conservation and other kinds of behind-the-scenes museum work (Marty, 2008, p. 132). Some in the field anticipate that by using these new information resources museums can make a stronger connection with the public. They postulate that this leads to more support for museums (Marty, 2008, p.132). Additionally, these new kinds of museum information can be used to make a case for the relevance of museums in a digital age (Economou, 2008, p. 152). A digital environment also facilitates the reuse of information (Economou, 2008, p. 149). As the quotation below demonstrates, a digital environment offers flexibility in that it allows museums to network museum information with robust and creative ways.

> The linking and cross-linking of ideas embodied in museum artifacts has been at the core of collection development and exhibit design, regardless of computer use. With increasing digitization, it is possible for such links to become more explicit (in the form of hypertext and hypermedia) and to accommodate more narrative and interpretation that the limitations of physical space allow. (Marty, 2003, p. 287)

This concept of linking information based on semantic properties instead of just by type or purpose can be used to network general information about museum objects with targeted information in several ways in order to meet the needs of museum professionals as well as museum visitors. Targeted information can include object descriptions, interpretative texts written for a particular population such as children, or for use in a specific context such as in a seasonal exhibit. Hence a digital environment offers museums an opportunity to present their collections in such a way as to alleviate social exclusion (Economou, 2008, p. 151).

A digital environment for museum information enables museums to create surrogates of their holdings, as well as distribute museum information digitally via many means including web technologies and on-location interactive technologies. In addition, interactivity can be added in either of these distribution contexts. Interactivity allows users to participate in the museum experience by giving them the capability to tag, comment, rate, author, organize, personalize and collect museum information as opposed to only consuming it.

Surrogates

A digital environment for museum information allows digitized artifacts to be networked with museum records as well as other information resources. Digitization initiatives within the museum community have brought to the fore issues surrounding museum object representation in the form of digital surrogates. However, digitization is merely the most recent approach to representation in a long history of museum object and museum information representation. For example, copies of Roman marble statues can be considered another form of surrogate. As with the famous Elgin marbles and their copies, discussion of digital surrogates in museum contexts touches on deeper issues of ownership (i.e., copyright and intellectual property) with which the museum community still wrestles (Marty, 2008, p. 33).

Debate surrounding the role of surrogates in museum contexts can be generalized to either viewing them as a point of division from the physical object or as a bridge to it. A major practical benefit of digital surrogates is the ability for museums to vastly expand access to their collections. Surrogates remove artificial barriers to access such as time and physical location (Marty, 2008, p. 33). By accessing digital surrogates over the web one can visit the museum at any time and from any place. In a digital environment the surrogate can be used in multiple targeted exhibits (Marty, 2008, p. 33). Additionally, surrogates enable museums to “offer world-wide access to the whole of the collection, large parts of which are often not on display” (Economou, 2008, p.150).

Many of the threats attributed to digital surrogates are tied to the issues of authenticity and representativeness. Some see surrogates as a barrier to the original artifact. From a pragmatic standpoint, some worry that digital surrogates dissuade online users from making a trip to the museum to appreciate the original artifact. Those considering the philosophical underpinnings of digitization worry that surrogates lack or lessen what Walter Benjamin famously described as the "aura" surrounding museum artifacts (Marty, 2008, p. 33).

On-Location Interactive Technologies

Understanding the in-person museum experience is of paramount importance in designing the presentation of content in a way that attracts, sustains, and enhances interest for the visitor. The museum gallery is the place where cultural heritage is displayed, described, and discussed, so understanding why on-location interactive technologies are controversial for the museum community is easy, even as these technologies become an increasingly common part of the museum experience.

Interactive technologies are digital environments (e.g., applications running on multitouch tables, podcasts stored on iPods, web-based museum activities) that "actively involve visitors physically, intellectually, emotionally and socially" (Economou, 2008, p. 138). The many benefits attributed to on-location interactive technologies in museum contexts will be explored in the next section, however, it is important to first discuss some basic concerns for incorporating these interactive technologies. A primary assertion is that on-location interactive technologies threaten important aspects of the visitor's museum experience, such as the visitor's engagement with the objects themselves or with other visitors. Concern exists that interactive technologies will negatively effect the social environment inside the museum. For example, a popular critique of headphone-based audio guides is their potential to discourage conversation among visitors. The merit of such claims regarding on-location interactive technologies must be studied in order to understand their effects on the entire museum experience.

Current Research into Sociotechnical Effects of Interactive Technologies in Museums

In a study of an application accessed on laptops, researchers observed that when provided the opportunity for interaction with a museum exhibit, visitors reported an increased sense of engagement (Falk & Dierking, 2000, p. 25). Additionally, an increase in on-site time spent with museum objects was observed when participants were provided access to interpretive descriptions related to the exhibit on view through laptops (Evans & Sterry, 1999, p. 113). Personal computers, cell phones and data devices are a popular means by which museums have provided interactive experiences. Yet it is studies of public information kiosks that are the most relevant to the One Butterfly project.

Public information kiosks are a popular platform for providing on-location interactive experiences for museum visitors. Kiosks were an early means of providing these interactive experiences. Information kiosks have been used in many contexts, for example, as labeling systems to support artifacts intentionally displayed in sparse viewing cases. Some kiosks of this type de-emphasize interpretative materials while others emphasize interpretation. When kiosks are associated with specific artifacts on display, several outcomes, both positive and negative, have been observed. A kiosk can support more information in terms of volume and media type. Additionally, labeling information stored and displayed electronically is both more economical and more easily updated. A kiosk can mitigate the need for printed labels, which some see as a distraction to a visitor's ability to focus on the physical object observed (Economou, 2008, p. 138). A labeling kiosk, however, can itself distract visitors if the kiosk is difficult to learn to use (Raisamo et al., 1999). During busy hours in the gallery, visitors may find themselves lining up to use a kiosk providing labeling information when multiple users could read a printed label. Information kiosks have also been used to provide background information and thematic interpretation outside a museum exhibit and can mitigate a gap in the understanding of an artifact, both as it appears in the museum and in contextually understanding its history. This is referred to as the "museum effect" (Economou, 2008, p. 139).

Kiosks are also used in entrances to museums. Examples of these have been employed as a resource for planning one's exploration of the galleries. To support planning, one kiosk of this type offered paths through the exhibit based on user's level of interest (Economou, 2008, p. 140). In addition, kiosks have been employed as a museum directory or map display. Kiosks have also been used in museums to allow visitors, especially children, to engage in activities that create digital souvenirs. The benefit of the souvenirs is to create an artifact of the visitor's experience that could potentially serve as a reminder of the visit and thus boost the visitor's sense of connection to the institution. There are no cited threats to kiosks used for making digital souvenirs but certainly there is a cost associated with the implementation and maintenance of these technologies.

Also cited in the literature is the application of kiosks used for reference and casual research as well as to serve as distributed information portals. This application of on-location interactive technology is closely related to the type proposed in the One Butterfly project. Economou explains reference and casual research kiosks are designed for a more protracted use and that often such kiosks are located in a comfortable room that also stocks other information resources (2008, p. 141). However, the utility provided by these types of kiosks has yet to be confirmed by empirical research.

As part of the museum community's continued focus on the end user experience, other research streams in museum interactive technologies not covered in this review include virtual museums, co-visitation, personalization, mobile computing and uses of web technology. Although on-location interactive technologies come with notable benefits enhancing the museum experience, not all implementations of such technology have been successful. Marty attributes this to a failure to consider the technologies employed in several contexts including the social, personal, and physical ramifications of those technologies' presence in the museum. In addition he cites another problematic practice in which museums base the introduction of interactive technologies on incomplete understanding of the information needs. Marty suggests, "the first step in designing and implementing new interactive technologies is to evaluate the changing needs and expectation of the museum's visitors, and to design solutions that meet those needs and expectations, providing opportunities visitors will actually use and enjoy" (2008, p. 135).

Further tempering enthusiasm for on-location interactive technologies is a realistic assessment on the information management work they entail. Interactive technologies in museum contexts have contributed to an explosive increase of information in museums (Marty, 2008, p.135). This increase contributes to a general increase in the amount of museum information. Although entirely feasible through the use of relational databases, there often is a lack of integration of information in the museum. Further, when museums publish more targeted information or allow visitors themselves to contribute to the descriptive record through tagging or similar web 2.0 techniques, there is an increase in the number of stakeholders.

Cross Institutional Data Sharing and Ubiquitous Computing in Museum Contexts

Despite calls for caution and probity when introducing on-location interactive technologies, the increase in the quantity and quality of networked museum information coupled with realizations of ubiquitous computing environments virtually ensures that on-location interactive technologies will continue to proliferate. “The theme driving much of the modern museum interactivity is that of constant integration, where access to all types of resources (behind the scenes, in the galleries, online, etc.) becomes uniform, seamless, and transparent” (Marty, 2008, p. 132). In the literature, interactive technologies have largely been discussed as a means of supporting a particular exhibit. However, the One Butterfly project was designed as a multitouch information kiosk to be used outside of the exhibit context; that is, not as a support system for the dissemination of targeted interpretive or descriptive information. Research into this area is scarce but with the blurring of online and on-location museum experiences, it would not be far fetched to imagine an interactive pan-institutional information kiosk providing item level descriptions such as that proposed in the One Butterfly project.

A similar project conducted by members of the ZKM Institute for Visual Media explored technological solutions for geographically distributed artwork. Economou describes their project as embracing the distributed nature of the artwork in that it "allows it to be manifested at numerous interconnected locations worldwide (one-large scale environment situated permanently at ZKM, Karlstuhe and four other designed to travel around the world, e.g., exhibited in Bratislava, Bonn, Rotterdam and Tokyo in 2003)" (2008, p. 142). While kiosks like this could be used to provide access to digitized museum objects across continents, another possibility is to use kiosks to promote understanding of museum objects within a smaller geographic context. In this vein, a kiosk could be used to promote inter-institutional visitation if pan-institutional collections are readily available to make connections between artifacts. In addition, networked museum information allows for sharing information across institutions. The Consortium for the Computer Interchange of Museum Information has noted, "the rising number of cultural institutional which started offering online access to digital surrogates of their collections, together with the developments of new technologies and protocols for searching across different databases made the possibility of cross-collection and cross-institutional searching and linking a reality" (Economou, 2008, p. 146).

IMPORTANT INNOVATIONS IN USER INTERFACE DESIGN FOR VISUAL INFORMATION SEEKING

A basic and recurring problem that we as interface designers confront is that there is more information than fits on the screen.

In the quotation above editors Shneiderman and Bederson sum up the motivations for this section of the literature review (2003, p. 83). In the last twenty years several important innovations in interface design have permeated personal computing and are now becoming commonplace on the web. Chief among these are display techniques providing overview and detail information. Notably, this is specified as a design requirement for the One Butterfly suite of interfaces described in the Design Opportunity section (p. 40) of this report. These techniques fall under the rubric of Shneiderman's

Visual Information Seeking Mantra, "Overview first, zoom and filter, then details-on-demand" (Bederson & Shneiderman, 2003, p. 365). These techniques include zooming multiscale interfaces, toolglasses, magic lenses and forms of focus+context interfaces. They offer an alternative to older techniques—paging, scrolling, panning, and spatial partitioning—each of which introduces discontinuity and increased cognitive load (Cockburn et al., 2008). The interface innovations covered in this section all share a common quality: they emerged as personal computing became more complex and ubiquitous at the same time researchers and developers sought better ways to manage more files, more information, more text, and more complexity than would fit on the screen at once. At the same time, each technique introduces problems of visual overload and disorientation that must be mitigated when providing information with enhanced flexibility.

Zoomable User Interfaces

Zooming is a common way to display detail in a user interface. Pad ++ (Bederson et al., 1994), a later release of Pad, was an important innovation in zooming user interfaces (ZUI). Historically, multiscale semantic zooming has been used for navigation and organization of information. Pad++ was a multiscale interface characterized by an infinite workspace navigated via smooth zooming. This system introduced the concept of semantic zooming in which, the degree of magnification changes the amount of content, size, or detail displayed for an information object (Bederson & Shneiderman, 2003, p. 84). This system used semantic zooming to allow for a continuous smooth trade-off between context and detail, thus removing the constraints of the screen (Bederson et al., 1996). ZUIs have evolved; now it is more common for ZUIs to provide overview windows to orient users at high levels of zoom. Previously, overview and detail information was available separately and was viewable at distinct levels of zoom.

Consider this scenario:

- *12:50:00 p.m. Jesse minds a Chinese province in a web-based map application.*
- *12:50:15 p.m. Jesse then zooms into the map to find the largest city in the province, but accidently zooms so far into the map that no markers are displayed.*
- *12:50:45 p.m. Jesse then pans around remaining at the highly zoomed-in view of the map to find the province's boarders to orient himself.*

In the scenario described above Jesse was disoriented for more than thirty seconds due to the high degree of zoom, which made the map application difficult to use. If the map application had supplied an overview window then perhaps Jesse could have quickly identified where in that particular Chinese province which he had zoomed into. Nonetheless, the overview window would have its own effects on user performance. Overview windows have been shown to have positive impacts on spatial recollection (Cockburn et al., 2008, p. 22). Even though both overview and detail information is immediately available, the information is separated by a zooming navigation act that can introduce disorientation due to the temporal separation of the actions (Cockburn et al., 2008, p. 31). Likewise, the next interface innovations discussed also risk adding too much complexity at the detriment of the user experience.

Overview Plus Detail & Focus Plus Context Interfaces

Paging, scrolling, panning, and spatial partitioning are suited for displaying linear textual information that is ordered in a sequential manner. This is considered one-dimensional data (e.g., program source, code, an alphabetical list of names) (Bederson, 2003, p. 365). By contrast, overview plus detail and focus plus context are two interface innovations that excel in the display of maps, images, and simple networked relationships

(Bederson, 2003, p. 365). In overview plus detail interfaces, a user interacts with each view separately, even though an action in one view affects the display of information in the other. Often this interface combines scrolling and panning in the detail view (Cockburn et al., 2008, p. 6). Toolglass, a landmark overview plus detail interface from Xerox PARC, introduced the see-through widget as a means of providing content and detail information at once (Bier et al., 1993). Unlike overview plus detail or zooming interfaces, focus plus context interfaces don't require a user to synthesize the "global relationship between views" which has been seen to decrease short-term memory load (Cockburn et al., 2008). Focus plus context interfaces, in contrast, have both focus and context views combined in a single interface.

There are a variety of contexts in which visual information seeking is a primary user task. Understanding these contexts is especially relevant to designing visual information seeking experiences such as in the One Butterfly suite of interfaces. For example, image libraries such as visual resource libraries on college campuses must support a range of image-seeking tasks from the very broad (web a studio art student looking for inspiration) to the very narrow (web a lecturer needing a copy of a thirty year old slide). Some innovations in interface design have been specifically targeted at information seeking task support. One Butterfly provides at least some components of the Agileviews framework presented in Geisler's dissertation particularly the overview, preview and history view (2003). In future iterations of the One Butterfly suite of interface designs the remaining view components—shared view, primary view and peripheral view—could also be implemented as a means of investigating the Agileviews concept on a non-traditional platform (Geisler, 2003). Despite the advancements in supporting visual information seeking, this remains a difficult kind of task to support in part because even metadata when present does not fully describe the contents of an image. An image without descriptive metadata is particularly difficult to find. Fortunately, the One Butterfly suite of interfaces is based on a rich collection of professionally cataloged and digitized images.

Interface innovations such as those described above offer several benefits, including promotion of exploration and elimination of the penalties of getting lost. Further, an interface that offers previews encourages users to engage. Offering overview and preview interfaces for browsing provides a user with a large amount of information without being overwhelmed (Bederson & Shneiderman, 2003, p. 85). Numerous evaluations of these interfaces have been conducted to measure the efficacy of these interface innovations' ability to improve the user experience in terms of document navigation, target acquisition, menu item acquisition, multipoint target acquisition, multiscale searching and steering tasks. Despite the evaluations of simple tasks such as those just listed, evaluations of more complex tasks are far less investigated in general. Notable in the findings, as reviewed by Cockburn et al., are two studies that indicated fisheye views outperformed both types of overview and detail interfaces. Based on Cockburn et al. writings it seems that the relationship between interface and interactions cannot be understated. The following section discusses multitouch interactions and technologies involved with expanding the One Butterfly suite of interfaces into a multitouch computing environment.

MULTITOUCH COMPUTING ENVIRONMENTS

Multitouch computing environments are not new. The first dissertation on the topic was published in 1982 and the pinch gesture was developed in 1983 (Buxton, 2009). A person using a multitouch screen can directly manipulate the object at his or her fingertips. As with multitouch screens, multitouch pads recognize multiple gestures but still are a form of indirect input in which a person's manipulation of an object is mapped from the pad surface to the display. For the purposes of this report, multitouch refers to direct manipulation on a screen. Indirect multitouch input, such as touch pads, will be specified as such.

Multitouch screens are a part of the surface computing movement. Surface computing is a discipline in which users interact with computing devices embedded in tables, floors and walls. It has grown in popularity in recent years as costs have decreased significantly (Terrenghi et al., 2007; Buxton, 2009). These surfaces combine input and output devices that allow users to abandon devices like mice and keyboards as gestures recognized by computer software.

Diversity of Multitouch Configurations

Multitouch technologies have risen in popularity as they have become increasingly less expensive. As with many recent technological advances, multitouch systems are increasingly employed in public spaces. The means of creating multitouch devices varies with configuration, equipment, and software used. Configurations of large-format multitouch displays often vary in spatial orientation (see Figure 2). Evaluation of multitouch systems often compare horizontal types (i.e., tabletop displays) with vertical types (i.e., wall displays) as well as comparing top and rear-projected displays (Everitt et al., 2006). Additionally, the size of display is a factor to consider with the multitouch configuration. Large multitouch displays can be difficult for some users to reach, especially when oriented horizontally. Multitouch displays that are small in size and or mounted low to the ground risk crowding taller users (Ryall et al., 2004).

Figure 2: A comparison of top and rear projected displays.

A horizontal orientation of a multitouch display, often referred to as a multitouch table, enables better face-to-face communication. This sort of orientation has become popular for systems designed to facilitate collaborative group work. Researchers of tabletop computing have investigated ways to mitigate information distortion resulting from the ability for groups to view the display from all sides. Designers of horizontal multitouch displays for use by multiple users struggle to create interfaces that aid group members' awareness of others work, as well as allowing for private workspaces and issues observed with territoriality in co-present collaborative computing (Ryall et al., 2004; Wigdor et al., 2007; Wu & Balakrishnan, 2003). Vertical displays offer a single view direction that can be both an advantage and a limitation. A vertical display orientation makes private or personal space in a public setting challenging, but this orientation can be advantageous when a shared view is sought. Depending on the height at which it is mounted to the wall, a vertical display can require shorter people to raise their arms for extended periods of time. This can be uncomfortable and tiring (Terrenghi et al., 2007).

The benefits of top-projected displays, such as DiamondTouch and SmartSkin, include the system's ability to interpret a person's hand shadows and interpreting touch. This combination of direct input techniques affords the interpretation of hover interactions, a limitation of rear-projected touch-only configurations (Dietz & Leigh, 2001; Rekimoto, 2002). Using hand shadows and direct-touch greatly expands the available interaction vocabulary. In addition, a top-projected display can transform a user's tilted hand into a private information display, something of potential benefit in a public setting. Top-projected systems sidestep problems experienced in touch-only configurations, which hinge on the system interpreting finger blobs of varying sizes correctly and consistently. The major drawback of a top-projected configuration is that users must obscure part of the display with their own hand or body.

Rear-projection displays offer the benefits of a concealed projector, so the user of such a display will not obscure the display’s projection with his body (Han, 2006;

Peltonen et al., 2008; Rekimoto, 2002). A rear-projected display is more mobile because it doesn't require a ceiling for mounting the projector. Additionally, it can be well suited to on-location use at an event, potentially by employing a tent to control light exposure. An angled orientation for the display makes it easily visible by groups while encouraging turn taking, since the system is not designed for multiple users. Unfortunately, much less is understood about the benefits and drawbacks of angled displays. One known drawback, however, is that angled displays offer a single view direction, thus preventing face-to-face communication. Angled displays also benefit from a single view direction in that view distortion, or information distortion, is less severe than horizontal displays (Wigdor et al., 2007). The social aspect of using large multitouch displays of differing orientation warrants deeper investigation.

Multitouch Information Kiosks in Public Environments

The literature on multitouch information kiosks in public environments, among other things, attempts to describe humans' interactions with these devices and suggests improvements in kiosk design. The social configurations observed in the use of multitouch information kiosks in a public setting are an important theme in this literature. The size of current information kiosks make shared experiences with a kiosk inviting. In that vein, the CityWall interactive window is a public information kiosk that supports a timeline application on a large, vertical multitouch display situated in a shop window on the street (Peltonen et al., 2008). While this interface is much more unstructured compared to One Butterfly's, including the ability to freely move and manipulate photos, many user behaviors observed in this system’s evaluation apply to One Butterfly. Most people observed interacted with the wall in pairs, the vast majority of dual interactions between people or groups being between relatives rather than strangers. Peltonen et al.

found that the majority of those users interacting with the wall in pairs or groups adopted social configurations, the most common being the teacher-apprentice setting "where one or more users took the role of an experienced or technologically savvy user. [...] assisting the other members of the group when needed" (Peltonen et al., 2008). The multitouch configuration proposed for One Butterfly would support interactions in pairs due to the single view orientation of the angled display, which is well suited to use in pairs. In a related work, Ryall et al. studied the effects of group and table size in a multitouch system. Although, users preferred a larger table, Ryall et al. found that table size did not effect how quickly users completed their tasks (2004).

In this literature the study of multitouch interactive systems in museums is of particular interest. Geller (2006) reviewed nine tabletop systems used in museums (p. 1). He noted the benefit of a table's familiarity and connotations of being used as gathering places, which Geller argued attracted users to interact in ways that the keyboard-mouse computer set-up did not (2006, p. 11). His review indicated that top-projected displays were dominant because this configuration protected expensive equipment from accidental damage (2006, p. 10). Of the review systems, the floating.numbers system was the most similar to One Butterfly in its functionality. Situated the Jewish Museum of Berlin, this system's display surface was entirely touch-sensitive and based on a commercial technology Sensitive Skin (Geller, 2006, p. 11).

Noting Geller's work, Hornecker (2008) conducted an empirical evaluation of a touch-enabled interactive system in a museum setting. Hornecker noted that the most complex interactions were not the most successful (2008, p. 1). The Tree of Life application presented in Hornecker's article was designed to support open-ended browsing (Hornecker, 2008, p. 2). Interestingly, the application interface used a branching visualization of search results. Unwittingly this concept was explored for One Butterfly. The branching visualization was presented as a first level interaction. A second level interaction involved abstract interactions with the growing tree of life. Similarly, One Butterfly's interactions offer several layers of engagement, as will be discussed in the Design Opportunity section. Hornecker's findings were based on observation and *in situ* interviews revealing that immediate apprendability and early success in interaction was key to a positive experience with the Tree of Life multitouch system.

Hornecker's findings support a more general finding in the usability of interaction techniques for multitouch information kiosk use. Raisamo's (1999) evaluation of the intuitiveness of selection techniques on multitouch information kiosks indicated that eight out of fifteen users needed prompting or coaching to perform a drawing task that was familiar to them in an indirect input configuration (p. 5). An information kiosk in a public setting needs to support first time users by presenting interactions with a low learning curve. The most intuitive and "simplest" selection technique evaluated, the time-based technique, was preferred by users (Raisamo, 1999, p.10). Helping users avoid selection error, the design of the One Butterfly multitouch interaction scheme designated simplified gestures for selection interactions. The next section offers a presentation of the literature related to supporting first time users with design of interactions for large-format multitouch systems.

First Time Users' Multitouch Interactions

Another important consideration to be accounted for in the design of a multitouch kiosk is acknowledging that most users will be first time users. This section describes the literature on supporting users in their initial interaction with a large-format multitouch system. The One Butterfly suite of interfaces is to be used as an on-location information kiosk in which the majority of users will be using the system for the first and perhaps only time; this influenced the approach to design One Butterfly's scheme of multitouch interactions. It seems much of the research into multitouch interaction is motivated by an interest in presenting common tasks from the physical world (e.g.,sorting photos) with greater flexibility (Terrenghi et al., 2007). Two usability objectives were identified in the literature to guide the interaction design of the One Butterfly system.

Objective one: do not intimidate users with the interaction and interface design. Users need to immediately apprehend how to use the system. Hornecker's study of visitors' behaviors interacting with a multitouch kiosk within a museum context found that visitors tend to first observe those using a kiosk to learn how it works. Other observed behaviors include users taking turns using a kiosk and engaging in "how-to conversations" (Hornecker, 2008, p. 7). The Master-Apprentice roles, identified by Peltonen et al. (2008), have the potential to make a system seem less intimidating but do not ensure it. Addressing this, Wu and Balakrishnan (2003) studied including simple interactions, some of which mimic the familiar cursor pointer. These interactions were adopted by a majority of the observed first time users when interacting in a multitouch environment. Understanding what interactions seem obvious or even natural to an uninitiated user of a multitouch system informs their approach. Epps et al. (2006), in an observational study, found that the extended index finger hand shape was used in the vast majority of tasks. The tasks observed with this gesture included: single selection, opening, slider moving, scrolling, and multiple selection.

Objective two: ensure that first-time users' experience success interacting with the system as early as possible during their first session (Hornecker, 2008, p. 4). Studies of multitouch information kiosks in public settings suggest two strategies to aid users in

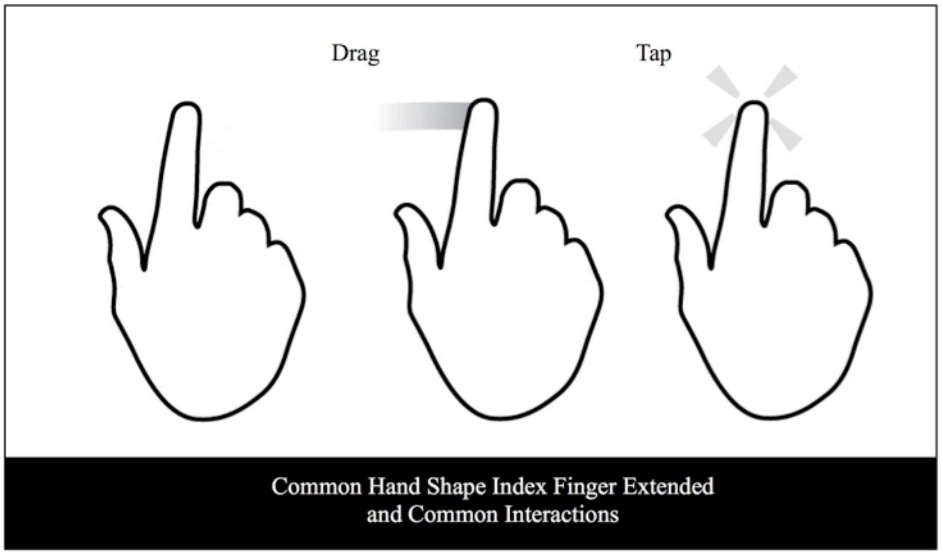

Figure 3: A potential aid to interaction hand shapes can serve as visual cues for users learning multitouch gestures.

acclimating to new interactions. A dynamic hand icon displayed on top of the interface can coach first time users how to interact with the system (for example, see Figure 3).

Prompting can be gradually removed from the display as users gain confidence (Hornecker, 2008; Everitt et al., 2006). Similarly, enhancing a kiosk interface with help systems such as a "question bubble" can assist users having difficulty and potentially salvage negative first time use experiences (Hornecker, 2008, p. 2). Implementation of the One Butterfly system would require acknowledging and accommodating user error, including checking for inconsistencies in interactions and interface design elements in order to mitigate confusion among first-time users.

Physical and Cognitive Constraints of Multitouch Interactions

As will be explained fully in the Design Opportunity section (p. 42), the design of the One Butterfly suite of interfaces allows a user to navigate through a history stream of cached images using a multifinger pan gesture. This mode of interaction was chosen to invite immediate use in a public setting. Still, in choosing multifinger and whole-hand interactions, some advantages and challenges of multitouch input were considered. Advantageously, multitouch interactions do not require external input devices such as a mouse or keyboard. This can reduce the barriers to computing for special populations. Some tasks can be completed more quickly than with a mouse and can be more easily learned.

Multitouch input also poses challenges, including varying sizes of users' fingers, hands, and heights. Some users' fingers will be too large for detailed work; other users' finger pads will be so small that they are difficult to track. In such instances, indirect input can offer greater control, precision and fidelity. Even with an understanding of the benefits and drawbacks of mapping tasks from physical to digital modalities, developing an interaction vocabulary supported by multitouch gestures is challenging.

The design of interactions involving multifinger input, with both one and two hands, comes with its own physical and cognitive constraints (Terrenghi et al., 2007; Wu & Balakrishnan, 2003). Although not distinct in terms of how input is interpreted, some interactions are better suited to multiple fingers on one hand, while others are suited to fingers on two hands. Interactions in which the points of control are separated (e.g., object rotation, 3D manipulation) are better suited to bimanual multifinger interactions. Supporting tasks in surface computing with an appropriate method of input and control is essential, especially in systems requiring low barriers for use, such as public information kiosks.

Mapping Input and Physicality in Multitouch Computing

Although multitouch computing has been a subject of research for almost thirty years, Terrenghi et al. contended that researchers have not yet considered the theoretical contexts of interfaces used in surface computing (2007). Addressing this gap, the authors list several research questions relevant to the One Butterfly project: "what aspects of the physical world should we be concerned with in the interface design of digital media? How do different aspects affect people's mental models and behavior in interaction? To what extent can emulating the physical world result in behavior[s] similar to [those] exhibited in the physical world (given that this is desirable)?" (Terrenghi et al., 2007, p. 1158). To engage these questions, the authors designed an experiment with two tasks: 1) assemble a puzzle and 2) sort photographs into three groups. Each task was to be completed in both physical and digital modalities.

In designing their experiment, the authors took care to map, as closely as possible, the actions in the physical world to the actions available to users when interacting on a tabletop-computing surface. In experiments like this, mapping between environments is crucial to the quality of an experiment's findings. With this study, Terrenghi et al. sought to uncover the "fundamental differences between interacting with tangible objects in three-dimensional space as compared to digital objects in two-dimensional space" (Terrenghi et al., 2007). They did so in order to see what influence the task modality—physical or digital—has on user behavior.

The results of this study were enlightening and some of the interaction choices presented later in this report for the One Butterfly interface are supported by their findings. The authors presented four major findings, in order of significance: 1) one-handed interaction was preferred when participants use the digital tabletop; 2) users' interactions during physical tasks highlighted the use of 3D space; 3) the physicality of objects influenced the way users completed the tasks; 4) users employed different strategies for isolating and focusing on physical and digital objects. Note, however, that the findings of this study are preliminary since only twelve participants were employed (Terrenghi et al., 2007).

Nonetheless, these findings indicate that designing interactions for multitouch computing environments is complex. Several axes must be considered: one-handed vs. bimanual interaction, symmetrical vs. asymmetrical bimanual interaction and hand dominance issues. Each is discussed below.

One-Handed vs. Bimanual Interactions

Though the digital tabletop was designed to support bimanual interaction from the user's perspective, the computing surface afforded a one-handed “mouse-like” interaction. This is likely a temporary norm and a product of the user's familiarity with a mouse. Indirect input, though difficult to learn, has become a norm affecting the user's approach to multitouch computing. As multitouch computing becomes more common, mouse-like interactions will recede.

Symmetrical vs. Asymmetrical Bimanual Interactions

Bimanual interactions were much less common for digital tasks. When bimanual interactions were observed, test participants predominantly used symmetric gestures even though the computer could also recognize asymmetric gestures. This highlights an incongruity in the way two hands are used in digital and physical tasks.

Hand Dominance

The authors observed that participants used their dominant and non-dominant hands differently when comparing interactions between task modalities. This suggests that two-dimensional space undermines an allocation of hands to asymmetrical roles. Nonetheless in asymmetrical bimanual interactions, hand dominance is a factor.

With this study, Terrenghi et al. made several important contributions. Based on their results, it is clear that mapping interactions directly from the physical world to a digital one is far too simplistic. From this study, a conversation can begin about how to support common tropes of interaction, including general posture and patterns of manipulation, getting scope and overview information, focusing on a single item or a set of items, holding items in ‘stand-by’ and creating spatial structures. These interaction tropes were central to completing tasks in both physical and digital modalities. Some aspects, but not all, of the physical world can be helpfully emulated in surface computing. Pure mimicry is not the solution; instead, the authors make clear that “we have to recognize what those physical affordances achieve for people when working with tangible objects, and ask how we can employ perhaps different methods to attain those same ends digitally” (Terrenghi et al., 2007, p. 1165).

The authors' findings raise additional issues for interaction designers seeking to orient users to direct multitouch input, an approach which offers users enhanced degrees of freedom. Terrenghi et al. noted interaction designers could require, and thus familiarize, users with asymmetric bimanual interaction, instead of designing for “mouse-like” interactions that at first might be more intuitive to users. In a later publication, Terrenghi et al. (2008) explore another option: compensating for missing physicality in the digital realm with techniques like magnetic snapping, elastic regions, and rubber-band boarders. These physical world cues could stimulate users to use hands in an asymmetric manner, as has been observed in physical world tasks. To create missing cues, visualizations can be incorporated into user interfaces to communicate depth, thickness and quantity.

Chunking and Phrasing Interactions in Multitouch Environments

A natural companion topic for multitouch research is tangible computing. Tangible computing is a discipline that allows the physical and digital worlds to blur and involves computer systems that understand familiar gestures the user employs with physical objects. Terrenghi et al. consulted tangible computing literature in their investigation into interaction affordances in multitouch surface computing (2007). They suggested that now is the time "to examine more deeply what specific aspects of the physical world and physical interaction are being drawn upon as a resource in their design" (Terrenghi et al., 2007, p. 1157). Specifically the authors looked into the way physical objects and actions are represented as metaphors. They were interested in temporally distributed interaction input and the continuity of interactions. Those interests were motivated by seminal work on "chunking" and "phrasing" as a means of problem solving (Buxton, 1995). Buxton's contribution of interaction chunking and phrasing was written within the context of an indirect input-computing environment (Buxton, 1995). Still, the concept that the design of interactions has an effect on cognitive load seems to apply to a multitouch environment. In Buxton's investigation into the effects of interaction styles on cognitive load, he presents two approaches to interaction syntax. One approach is to design interactions according to the "single operand per verb" criteria, e.g., to cut and paste each require a separate command has at least four parts: select, cut, move cursor and paste. Another approach better suited to multitouch environments is to encompass the entire interaction into a single gesture so that the operations of selection and movement flow together. The benefits to this approach include a strong mapping between the movement of the user's hand and actions occurring on the screen. This approach reduces cognitive load by packaging gestures in the vernacular of activities in the physical world. The use of this approach in a multitouch environment is a more natural fit compared to an indirect input-computing environment.

Design Opportunity

The Smithsonian Institution has an impressive collection, in both size and quality, with which to interest the American public. Even after a massive digitization effort, however, the Smithsonian lacks the digital environment necessary to successfully connect the public with the organization's collections as a whole. An appropriately sophisticated interface has the potential to connect related resources across this large, decentralized institution. The purpose of the One Butterfly project, then, is to develop an alternative interface and interaction scheme for the CSC. The next section is a review of the existing CSC interface, which is followed by an overview of several components of the One Butterfly project including a description of the intended user population, design requirements, suite of interfaces, and lastly a description of the interaction scheme.

THE CSC INTERFACE

The existing CSC interface consists of four primary areas (see Figure 4). The largest area (a) on the screen encompasses the center region, where a ranked list of search results is displayed. The search results are comprised of small thumbnails presented along with a labeled display of metadata. The results are ranked and grouped into pages, which a user can navigate serially. Along the top of the page is a header featuring the primary search box (b). Along the left side there are two areas. The topmost area of these provides users with an input box to modify and resubmit a query (c); the final area is located on the remainder of the left of the screen (d). In this area is a presentation of aggregate counts of results organized by facet.

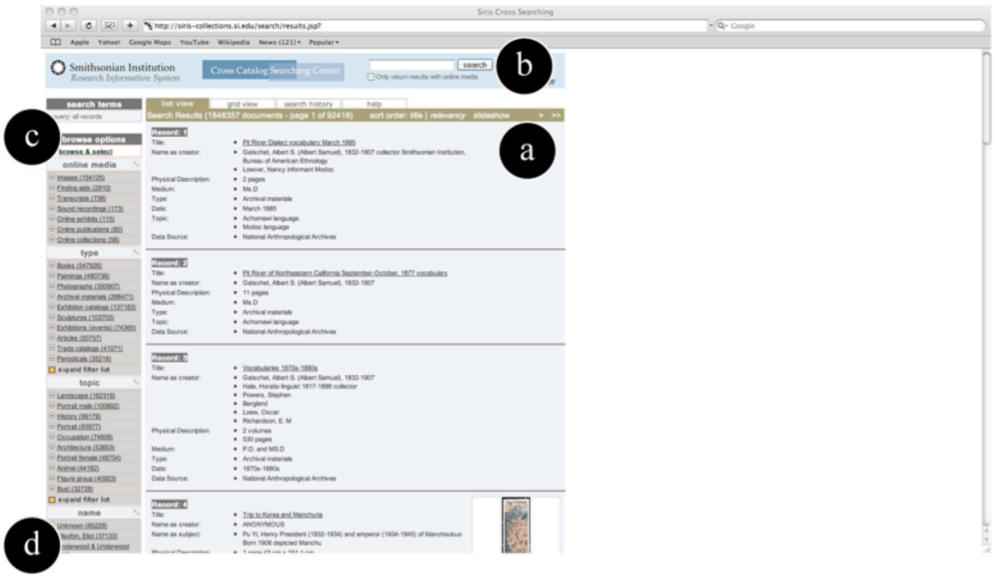

Figure 4: The CSC looks and behaves similar to generic library catalog system; it consists of four primary areas

The tasks and activities are supported according to their location within the four areas. The search results are presented in order of their calculated relevance ((a) in Figure 4). The content of the images is not considered in this calculation. Instead, the mechanism for retrieving these search results computes relevance based on the metadata and any other text associated with records. The presentation of the search results as well as the individual detailed records associated with each result favors the display of textual information with less emphasis given to the display of images (see Figure 5). This results in a textual interface together with a thumbnail image component. The search box ((b) in Figure 4) supports keyword searching; this is the primary tool by which users enter the collection. The query modification tool ((c) in Figure 4) serves as an interface element to provide feedback on the entered query while also allowing the user to modify the query without beginning a new search. Faceted browsing i.e., as browsing by attribute values of various informing aspects of the items returned; ((d) in Figure 5) are designed for further the refinement of search results.

Figure 5: The existing CSC interface includes a detailed record viewer, which favors data over the display of the image.

Faceted browsing interfaces are built to support the display of structured information, most often in the form of a markup (web XML) or in the form of a relational database (web MySQL).

Consider the following application scenario for the existing CSC interface:

Marie, an art history graduate student, is looking for examples of Japanese paintings depicting rural life in feudal Japan. She wants to find several good images to use in a class presentation on Japanese Art. Marie enters the keyword query "Japan farm rural painting" into the search box. Despite their small size, she notices several beautiful images, some more relevant than others. She employs the modify search box to remove "farm" from her query and waits for the page to refresh. Once the new images are loaded, Marie is ready to choose some for her assignment. Using the faceted browsing tool, Marie narrows the results *returned, limiting them to the years between 1185 and 1333 encompassing the Kamakura period. She clicks on several images and reads their metadata; to do so, she often employs the use of the browser back button to navigate between detailed item records and the search results page. Eventually she finds three images to show in class.*

The existing CSC interface operates much like a library catalog website. This type of interface is suited to searches for known items. Having a clear idea of the task and related results, Marie found images for her presentation, using all four major areas of the website. This interface performs equally with many other search interfaces for the retrieval of structured data. However, a collection of such rich variety could be used in several other information-seeking contexts. Exploratory, image-oriented information seeking is addressed in the following description of a variety of components of the One Butterfly project.

ONE BUTTERFLY

The work encompassed in the One Butterfly project is broad and deep. Earlier in this document a through explanation of the Smithsonian as an organization was given. In the previous section a description of the existing CSC interface was provided to give a concrete means for understanding how the One Butterfly project in a departure and advancement for the Institution. In order to further enrich the context provided for the main design contribution of this project, the suite of interfaces, the following sections describe the user population, design requirements, and interaction scheme around which the suite of interfaces was conceived.

User Population

One Butterfly was conceived to serve a broad population of the following: museum laypeople, culture and art enthusiasts. Based on 2008 numbers, the Smithsonian reports twenty-four million on location visitors but, remarkably, more than seven times that number of visits to the website. "As digital technology accelerates and the web becomes an even more essential part of our everyday lives, that number will grow, possibly reaching billions" (Smithsonian 2.0 About, n.d.). Despite an impressively large audience, Smithsonian is still failing to capture the interests of cultural-enthusiasts as efficiently as the New York Times' website captures news junkies or Twitter captures digital extroverts. Not enough is known about this group of people who love artistic and cultural history but only have opportunity to indulge those interests during free time, such as weekends and vacations. Other segments of the population have traditionally been courted by museum technology initiatives. Education and resources for children and families visiting the museum have been a productive area of research.

Design Requirements

Based on this user population the One Butterfly suite of interfaces had to meet several design requirements in order to maintain a balance of aesthetics and functionality, the most nebulous of which was attractiveness. Attractiveness refers to "the degree to which a person believes that the [product] is aesthetically pleasing to the eye" (van der Heijden, 2003, p. 544). In a confirmatory study, Tractinsky conducted three experiments to test the robustness of seminal Kurosu and Kashimura's finding that interface aesthetics play a role in people's attitudes towards computerized systems that was previously under acknowledged (1997, p. 116). The study concluded that there was in fact a significant relationship between aesthetics and perceived usability, but that the valuation of the aesthetics is culture dependant (Tractinsky, 1997, p. 122).

The user environment for One Butterfly was an important consideration in the design decisions made. The notion of a user navigating from one document to the next, in a sense moving from place to place on the web, was deemed inappropriate for One Butterfly. Instead of a series of web pages, the One Butterfly interface suite was designed to provide an environment similar to Agileviews in which the user is able to manipulate objects and view them in different ways without navigating through a series of web pages (Geisler, 2003, p.3). To achieve this the following requirements were defined:

1. Allow the user to focus on the task at hand.

- Hide or de-emphasize buttons and other interface elements when they aren't in use.
- Design the interface to seem to the user a single tactile environment.
- Design the system to avoid reloading the page to resetting the results page count.
- Allow the user to elect to view results with the metadata, to maintain focus of beautiful imagery.
- Allow the user to view many images at once.

2. Emphasize browsing and discovering in the interface's design.

- Design the system to allow the user to browse in many different ways.
- Don't display extensive detailed information or highly faceted data displays.
- Allow user to group (pile) images of interest without asking the user to explicitly know why they wish to group images. Avoid labeling groups until needed or necessary.
- Design the interface to emphasize ease of scanning over exhaustive text.
- Allow the user to save and sort the items they discover in exploratory search.
- Treat individual search results as discrete physical objects that can be grouped together.
- Honor museum informatics' object centric approach to information handling and display.
- Store session information and allow the user to exploit that information to sort saved results.

- Allow users to exported saved results as a zipped file even if the user has not elected to sort those results.

Suite of Interfaces

The concept for the One Butterfly suite of interfaces is an immersive, exploratory search environment comprised of three primary interface types: a contact-sheet search interface, a record detail viewer and a history stream visualization with personal information management tools.

Reviewing each interface type in more detail, the contact-sheet style interface consists of six major areas (see Figure 6). In the top right corner is a search box (a), moving to the right is a simplified and limited set of browsable categories (b), on the far right is a set of topicality explorers (c) these are large icons both described with pictures and labels that could reduce user error. From the top, running down the vertical center of this display are two virtual curtains that conceal meaningful sorting and filtering areas from view (d). These areas are used to provide the user with a visual space in which the user can sort and save results. The bottom of the interface holds the user's attention. There is also a work area, consisting of an intentionally empty area of the screen upon which users can pile and group saved results (e). Lastly, the largest portion of the screen holds a contact sheet of image results (f), the metadata for the images requires and interaction to display (see Figure 6).

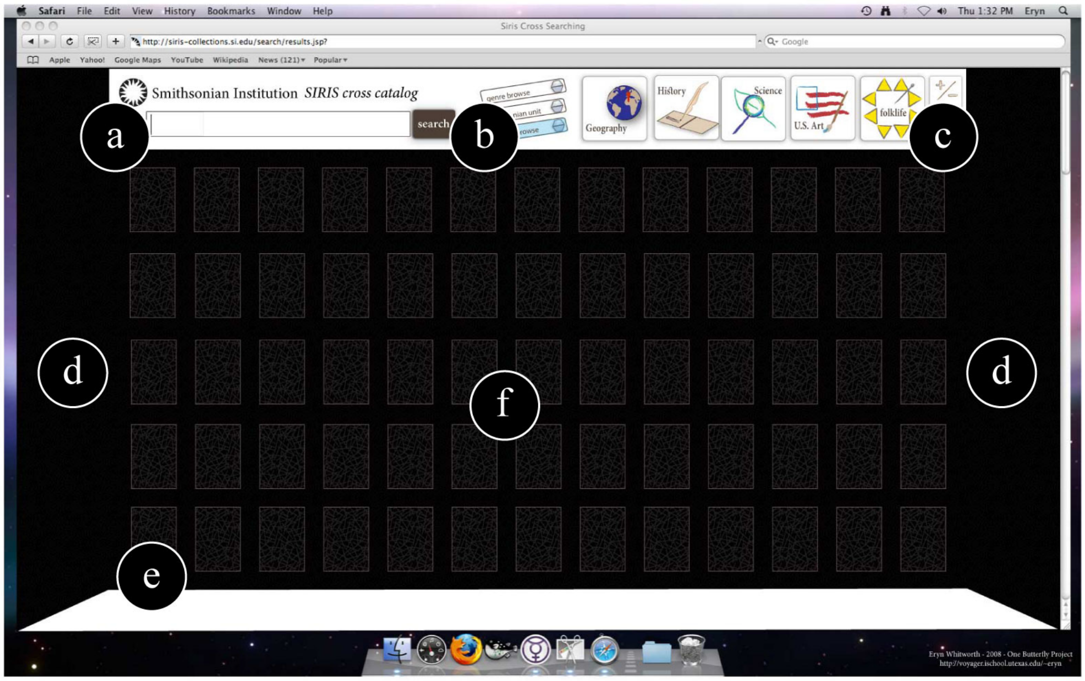

Figure 6: The One Butterfly Contact-sheet style visual search interface would be the primary interface for exploratory search of digitized images taken of 1.7 million Smithsonian holdings.

The second interface is quite simple. The record detail viewer is comprised of a direct yet sparse presentation of image and metadata (a). This area is situated on top of the display overlay (b), which dims the background scene and provides for toggling the darkened overlay on and off (see Figure 7). As compared with the existing CSC interface for record details shown in Figure 5, One Butterfly favors large images over presenting more metadata.

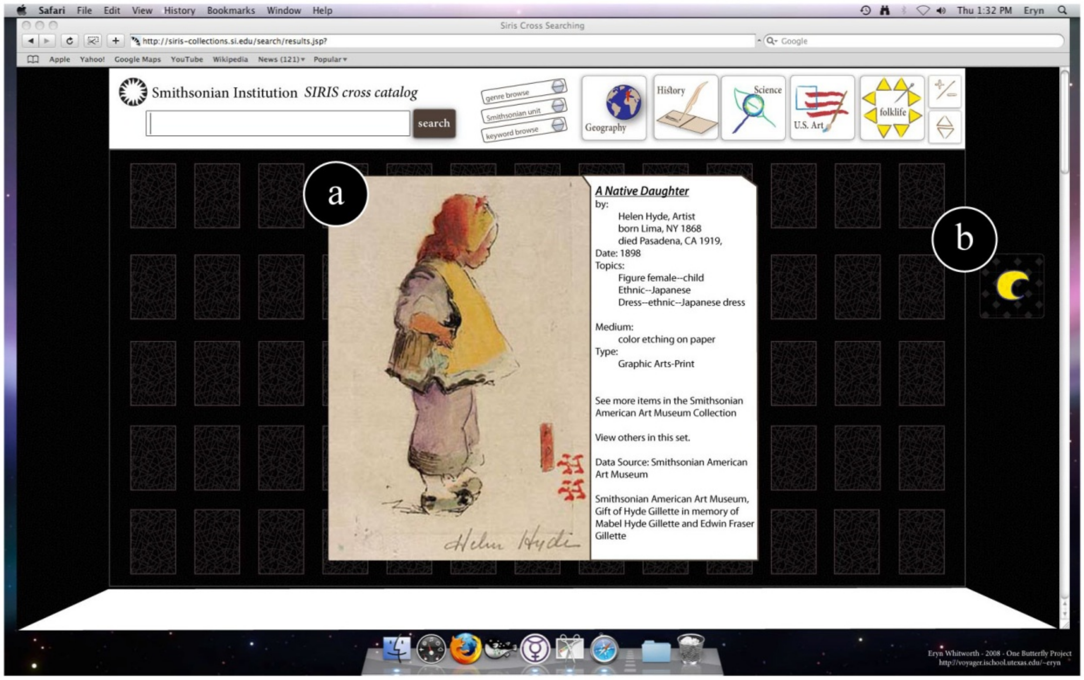

Figure 7: The One Butterfly Record detail view interface is an isolated display of metadata and full size images. Future iterations on this design will include a timeline interface.

The third major interface, shown in Figure 8, is named the history stream and has four major areas. Similar to the record detail, this interface has a toggle-controlled and dimmed overlay (a) that separates the second major area from the background view of the contact-sheet style display of image results. In addition to a toggle dimmer, this area includes a button for navigating through the temporal span of saved image results. That second area is comprised of temporally organized clusters of saved image results (b). The clusters are labeled to orient the user to where the are in the history stream of their saved results. Beneath the clustered results are labeling tools (c) to present a means by which to group images.

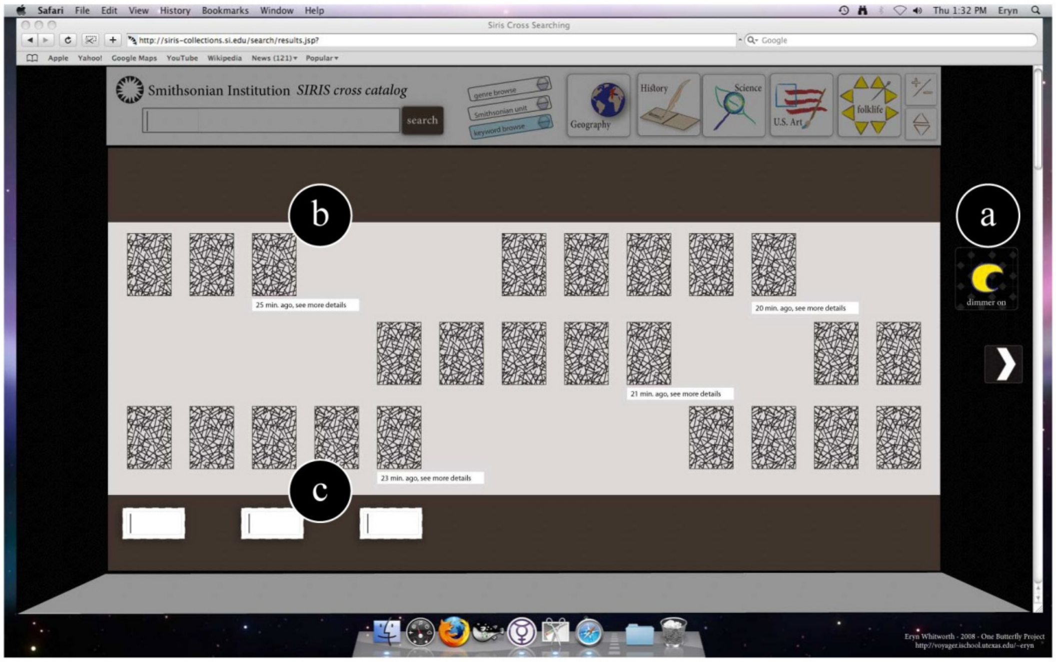

Figure 8: The One Butterfly History stream interface is a timeline visualization tool for users' favorite image results with personal information management tools.

Consider the following application scenario for the One Butterfly interface:

> *Jolene is a 5th grade Social Studies teacher visiting Washington D.C. during a day-trip. She has traveled into the city to visit the two art museums. When Jolene approaches the multitouch kiosk in the lobby of the American Art Museum, she was not looking for anything in particular. Nonetheless she was intrigued by an opportunity to search the Smithsonian's vast collections. Excited to "try it out," Jolene entered a seasonally topical query "cherry blossom festival" using an on-screen keyboard that appeared when she tapped the search box.*
>
> *Jolene discovered that the images tiled across the center of the display could be moved and expanded. She looked closely at several items and read the data presented. She noticed that she could browse her search results by the search unit*

Smithsonian Institution. Jolene chose to narrow her search further, choosing the American Art Museum. Engaged in her search activities, Jolene discovered she could store her favorite search results by dragging them one-by-one to the far left of the screen. Jolene understood that she was in semi-concealed portion of the interface because when the dragged image was placed in that area a small brightening of the screen occurred in addition to a notification that the image had been saved.

Jolene then reviewed her stored search results. The images were clustered based on time. In the course of her interaction, Jolene had submitted three queries and had saved results from each. Using the history stream interface, Jolene was able to detect the temporally clustered results had presented a de facto organization of her results by topic.

Selecting among the more interesting results, Jolene compiled and labeled images in order to send her self an email with the information. Jolene learned that she could continue her experience at home, using a web version of the application. She submitted her email address and went on about her day trip.

These interfaces, as is evidenced in the scenario above, are supported by a scheme of interactions design for a large-format rear-projected multitouch display.

Interaction Scheme

The One Butterfly design project includes some interaction sketches for the interface. A review of the design elements used in the three described interfaces is provided with an indication of the associated gestures supported for interacting with these design elements (see Table 1). Figure 9 illustrates that the gestures support the five unique interactions encompassed in the application scenario described above. Table 1 lists design elements mentioned in the scenario and interaction description below, which interface the elements appear in and what gestures would be supported. A description of the gesture supporting each interaction follows, noting however that there is not a one-to-one mapping of interaction to gesture. Gestures are italicized and labeled for easy identification in the gesture diagram (see Figure 9).

Design element	One Butterfly Interface			Associated Gestures					
	Contact sheet	History stream	Record detail viewer	Single tap	Drag	Drop	Pan	Stabilizer	Press & Hold
Image thumbnail	✔	✔		✔	✔	✔		✔	
Search form	✔	✔		✔					
Label pile form		✔		✔					
Email form		✔		✔					
Drop down menu	✔	✔		✔	✔				
Topicality Icons	✔	✔		✔					
History Stream		✔					✔		
Dimmer switch		✔	✔	✔					
Advancer button		✔		✔					
Image bin	✔								✔

Table 1: Matrix of design elements, interface, and gestures.

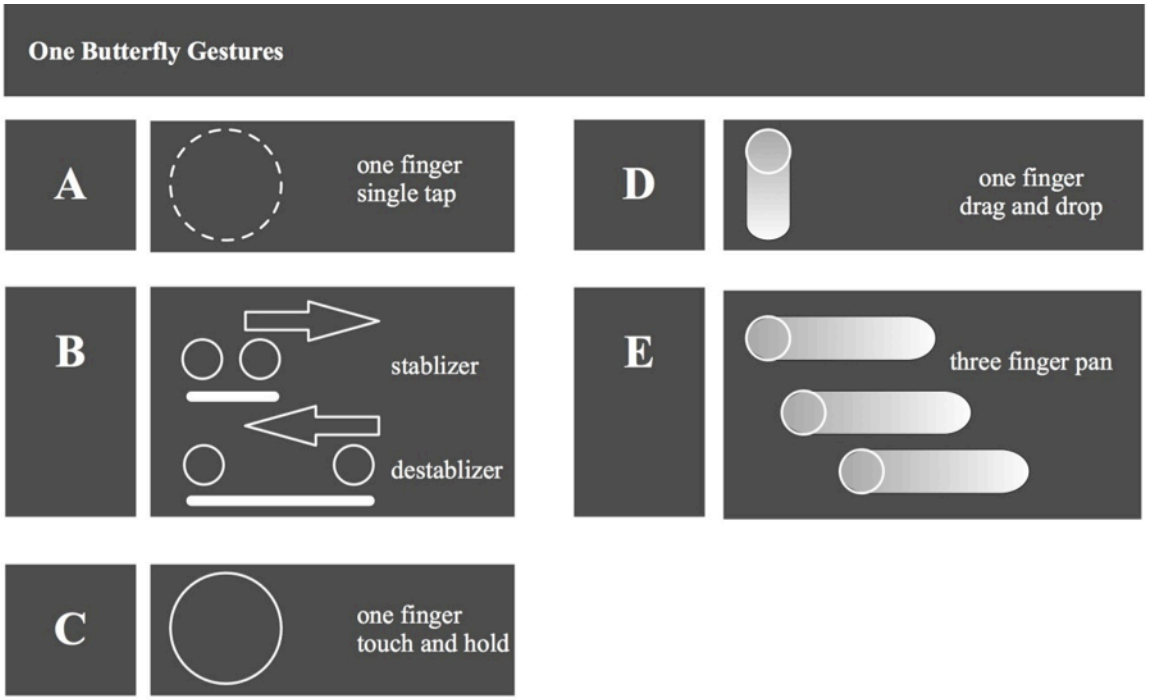

Figure 9: Five primary multitouch gestures supporting interaction with the One Butterfly suite of interfaces.

1. Enter and submit search. As an example of how text input is handled in One Butterfly, a user makes a single finger tap or 'tap' gesture (A) in the search form and on screen keyboard appears. The user taps the keyboard to enter letters, then taps the on-screen return or enter key to submit the query.

2. View detailed records for a single and multiple results. The production and viewing of detailed records for image results is a core interaction in One Butterfly. Anywhere thumbnail images appear in One Butterfly, a user can perform the following interactions: 1) review a single image, using a tap to bring up the detailed record viewer interface. This selection interaction enables the user to select thumbnail images. The tap gesture operates as a toggle. When a user taps, a thumbnail will be selected; if tapped again, the thumbnail will be deselected; 2) reviewing multiple images, a more complex interaction, uses the stabilize gesture (B). This gesture is used to enter into a multiple-selection-mode. With an index and middle finger employed together, the user touches the first image thumbnail and then spread the fingers apart while maintaining contact with the display. At this point the user can remove the hand, which signifies to the system of a change to multiple-selection-mode. The user may then select more image results using the tap gesture. In multiple-selection-mode a single tap merely selects but does not open the thumbnail image as a full size image in the detailed record viewer. As image thumbnails are selected one-by-one, each gains a faint halo to provide user feedback. When the user has finished selecting, a destabilize gesture is performed by placing spread index and middle fingers back on the display, drawing them back together. This signifies an exit from multiple-selection-mode. All of the thumbnails selected, including the first one, opens a modified record viewer interface using a slide show-like layout (see Figure 10).

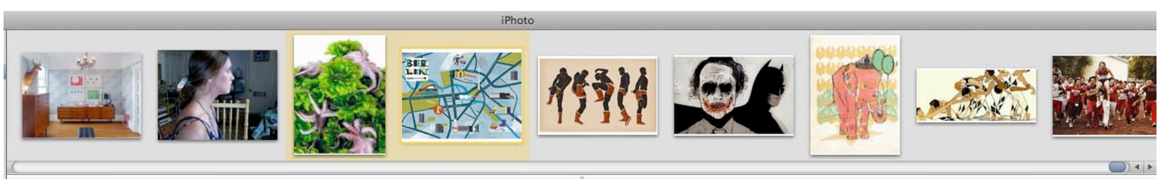

Figure 10: An example slide show display to augment the One Butterfly detailed record viewer interface.

3. Browse by facet. To browse using one of the drop down menus in the interface, a single finger touch and hold gesture (c) is used to open the menu. The menu then displays a highlight overlay, while the user maintains contact with the display and employs the single finger drag gesture (c) to drag their finger up or down to indicate the users selection within the drop down menu.

4. Drag and drop favorite results in area off screen. To cache interesting image results a user can again use a single finger touch and hold gesture before moving a image surrogate image into the off screen area. The user will know they've held the image for a sufficient amount of time because an iPhone-style shiver animation will indicate the image can be moved using the drag gesture (d). When the users has dragged the image to an appropriate area for dropping, an ambient highlight animation from behind the curtain. The interface described is depicted on p. 45 Figure 6 (d). This will indicate to the user it is appropriate to drop the image. The drop gesture just involves the user removing their hand from the display once they've placed the object in appropriate area for dropping. Different from a desktop-style drag and drop interaction the user may only drag certain objects. In addition, a user may only drop an image in prescribed locations.

5. Review saved results within a history stream. The interaction for navigating the history stream involves a pan gesture (e) in which the user places three or more fingers from one hand on the history stream (see Figure 8, b). The user then makes short passes in either a left to right motion, with a right motion moving forward in time and a left motion moving backwards in time.

6. Drag and drop images into piles. Just as with dragging and dropping thumbnails for off-screen caching, thumbnails in the history stream may be dragged and dropped onto the stage area (see Figure 8, c). The stage area looks and behaves much like the Mac OS X dock (see Figure 11).

Figure 11: The history stream “stage” area of the interface is proposed to behave similar to the Mac OSX dock.

Discussion

The One Butterfly project started as a design exercise to express ideas about supporting visual information seeking in museum contexts. The existing CSC interface was designed to support the needs of users trying to fill an acute and immediate information need. In contrast, the One Butterfly interface is intended to benefit the layperson in discovering hidden relationships between different Smithsonian materials and indirectly the relationships between Smithsonian units. These discoveries can be captured for later use by allowing users to group, label search results and send an email to themselves with that information. Another potential benefit is the ability to access the CSC during a visit to one of the Smithsonian's popular museums. A multitouch information kiosk, situated within a museum lobby or atrium, could provide an excellent resource to assist in trip planning and contextualization of the objects on display with the scores of objects housed in different locations, many of which are not on public display.

Despite these benefits, there also exists a great potential for complexity in terms of implementation, design and instruction on how to use such a system and for that reason a literature review for three major topic areas was undertaken so as to understand the underpinnings of the ideas espoused in One Butterfly.

However, some limitations in One Butterfly's conceptual model, previously unforeseen, have become increasingly apparent. A major theme of the museum informatics literature has been the development and use of technology to enhance the educational purposes of the museum. Museum services in the last twenty years could be characterized by their dual focus on education and technology (Economou, 2008, p. 152). The One Butterfly project, however, was not conceived as an education tool. Addressing this limitation in the One Butterfly interface would require significant changes. Pragmatically, this limitation is problematic to address, simply because developing educational content for all of the Smithsonian’s holdings is itself a mammoth undertaking. The scale of the Smithsonian’s collections influenced the design of the One Butterfly suite of interfaces. Tailored item level description is not feasible with a collection of this size. Not exhibit-based, One Butterfly supports a different kind of information resource than those most commonly used a museum. Instead of supporting a single museum exhibition which is the common tact, the One Butterfly suite of interfaces offer an opportunity to explore the Smithsonian entire digitized holdings.

The One Butterfly suite of interfaces does not provide for extensive personalization, though simple personal information management tools are included in its design. Personalization has been an important area of development in museum technology. Critics contend that extensive personalization in a museum setting risks the museum's role in offering a shared experience with objects of cultural value. Others suggest personalization in museum technologies is an important service tool that museums should offer in order to compete in an increasingly competitive entertainment marketplace (Economou, 2008, p. 152). More thought on this potential benefit of personalization in One Butterfly is needed.

The interface suite was not designed as a collaborative information kiosk in which users might share the interaction with others. Sharing a museum experience through co-visitation has become an area of research in which designers attempt to facilitate conversation among patrons both online and on-location (Marty, 2008, p. 134). Providing ways for sharing interaction within One Butterfly might increase its appeal and perceived usefulness. Related to this theme, One Butterfly's design is also limited in its provision for collecting and displaying user-contributed content, both as comments and descriptions. The advent of web 2.0 has changed the conversation about authority and public participation in the museum and user-contributed comments could be a feature One Butterfly users would expect.

MUSEUMS IN THE NEXT DECADE

The design of effective museum website interfaces has been a topic of interest for many years; soon, however, museums will likely be expected to offer much more in the way of innovative approaches to improving access issues. Acknowledging these increased expectations, museums continue to look for better ways to communicate with the public. Employing improved on-location interactive technologies is one way museums can make a case for their continued relevance.

While it is encouraging to see museum technologies increasingly embrace social media in these uncertain times, Twitter, Facebook and Flickr are merely other means for the online connection with the public. Museums, however, will soon have to address a convergence of computing environments. Soon users will access museum information on very different devices (e.g., multitouch tables, smartphones, tablets and personal computers). The quality and qualia of the user's museum experience will need to be harmonized across a growing diversity of devices. Thus finding ways to achieve this harmony of the user experience across multiple computing platforms will become important a topic of research.

Conclusion

This report was written to document and ultimately reflect upon a year-long design project, the One Butterfly suite of interfaces. This report first examined and discussed the existing information technology management practices at the Smithsonian Institution. Numerous existing practices were identified that have undermined the Smithsonian's attempts to sensibly aggregate and distribute collection information. Despite their efforts, several documents published by the Smithsonian Institution indicate that they continue to seek innovative and improved access solutions for approaching these long-existing problems.

A broad and multifaceted literature review was presented to ground the One Butterfly design project within fields of museum informatics, user interface design, and multitouch interaction design. Four fundamental challenges with museum information are identified and discussed based on a synthesis of the fifty-year history of museum informatics. The benefits and limitations of the digital environment for museum information were discussed and current research into on-location interactive technologies indicated that the One Butterfly design is a promising technological idea. Its implementation, however, would have to acknowledge and then overcome many common obstacles in order to achieve a more successful technology solution. Innovations in interface design, particularly the design of overview and detail views of interfaces for visual information seeking, were identified and discussed. It was clear that a balance is needed between information density and interface complexity. Additionally, careful consideration for the co-presentation and synthesis of overview and detail information is also needed. An analysis of the benefits and drawbacks of large-format multitouch configurations suggested that some heuristics based on the study of multitouch information kiosk usability could inform the design of first-time use kiosks. In terms of multitouch interaction design, literature investigating the physical and cognitive constraints of this form of input were explored. Included was a comparison of the affordances of direct vs. indirect input. Forms of direct input covered include parallel gestures in manual and bimanual interactions. This literature review informed the design of the One Butterfly suite of interfaces.

This report describes a design opportunity after an examination of the existing federated search interface used at the Smithsonian and its design shortcomings. The One Butterfly suite of interfaces was presented as a design solution. A detailed description of the interface components, their purpose, and their functionality, along with proposed multitouch gestures and their associated interactions was provided. To illuminate how One Butterfly might be used, two user scenarios compared and contrasted the user experience design of both the existing CSC interface as well as the One Butterfly design. Finally, a Discussion section outlines the limitations of the One Butterfly design and suggests potential areas for further evaluation and development.

To summarize, this report explained the *what*—the One Butterfly suite of interfaces, the *why*—the relevancy of this project at the Smithsonian particularly and its place in the future of museum informatics generally, in addition to the *how*—a solution for presenting a visual federated search of 1.7 million Smithsonian records that leverage the benefits of recent innovations in the field of human computer interaction.

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