Abstract

In this paper, we apply a concept driven interaction design approach to introduce a design theory for the presentation and navigation of digital art collections. This involves the realization of the design as a working artifact. Our approach aligns with efforts by art galleries and museums that embrace digital media. Our research raises the question of how gesture-based interfaces and novel interaction approaches can be used to provide non-linear information seeking experiences as compared to more conventional affordances for online museum collections, such as search and faceted browsing, or more traditional formats, such as print media and catalogues. We employ a unique interaction design based on the notion that, within museum collections, showing the context and relationships that surround individual objects creates a valuable web of meaning. It exploits the idea that the digital medium affords the ability to express the multiplicity of these relationships.

Keywords: Design Science, Interaction Design, Breakthrough Ideas in IS
Introduction

In this paper, we present a design theory of Information Systems (IS) for the interactive presentation and navigation of digital art collections. This comprises the realization of the design as a working artifact, an iPad app. The research raises the question of how gesture-based interfaces and novel interaction design can be used to provide non-linear information seeking experiences for art collections as compared to more conventional approaches, such as search and faceted browsing, or more traditional formats, such as print media and catalogues.

Our artifact employs a unique interaction design based on the notion that, within museum collections, the meaning of individual objects are determined, in part, by their relationship to other objects (Cairns, 2013; Skov & Ingwersen, 2008). Our design exploits the idea that the digital medium affords the ability to express the multiplicity of these relationships (Hooper-Greenhill, 1994) as compared to physical exhibitions and print publications. It utilizes concepts that are historically grounded in work from the early 1990s when the idea of the “virtual museum” was first mooted (Hoptman, 1992; Schweibenz, 1998). In particular, our design makes use of Schweibenz’s (1998) notion of “connectedness” as a means of linking objects together; an idea that describes the conception of a virtual museum as one that follows visitors' interests and perspectives on the works, rather than as one that offers fixed, curatorially defined views on the collection (Davis, 1994; Hooper-Greenhill, 1994).

The paper is structured as follows. In the next section, we elaborate our research approach that incorporates both design science and concept-driven interaction design (Stolterman & Wiberg, 2010). This is followed by the conceptual exploration of the design challenges: the identification, presentation and discussion of the guiding design metaphors of pathways: the concept of the information flaneur and information landscapes; and of the design principles which are derived from this analysis. The paper then presents the working design artifact with a focus on how the design principles are deployed to realize the generation and navigation of pathways and how the aesthetics of its interaction design convey an experiential quality of interaction with digital art collections. This comprises our descriptive and analytical evaluation of the artifact, which we then use to support the development of our design theory.

The Research Approach

Our work follows the methodological approach of design science research but also incorporates key elements of concept-driven interaction design (Stolterman & Wiberg, 2010). Design science research has developed into a distinct research approach that has growing recognition (Hovorka, 2010). There are several approaches to design science, such as those described by Hevner et al. (2004), Peffers et al. (2007), Kuechler and Vaishnavi (2008), Pries-Heje and Baskerville (2008) and Sein et al (2011). All have the general structure of ‘problem identification-design/build-evaluate-theorize’ (Hovorka, 2010; Winter, 2008).

Our particular approach to design science research is inspired by Åkesson et al. (2010). In line with these authors – with no obvious organizational problem to solve – we explore design challenges and derive design principles from existing knowledge, build a working artifact, and then evaluate the artifact in an acceptable, analytical manner (Aalst & Kumar, 2003; Hevner et al., 2004). In doing so we provide a design science theory, which fulfills Gregor and Jones’ (2007) criteria for such a theory that includes a description of the purpose of the designed artifact, its theoretical constructs, its principles of form and function, the artifact’s mutability, its testable propositions, kernel theories and justificatory knowledge as well as the implementation principles and the expository instantiation: the working artifact (prototype) itself.

In design science research, while it is common to employ focus groups and ethnographic research to inform its problem identification phase, an alternative approach uses existing theories and phenomena to guide new design explorations (Hovner et al. 2004). More specifically, we follow a concept-driven interaction design research approach (Stolterman & Wiberg, 2010) to envision a theoretical idea as a working artifact. This approach recognizes design science as a search process (Hevner et al., 2004) and is suitable for exploring new design ideas that may fall counter to existing and predominant user-centered design approaches (Greenberg & Buxton, 2008). These approaches, while valuable for identifying
problems and incremental improvements in existing design conventions, are criticized for their potential to quash radical or uncontested interface innovations. Similarly, Norman and Verganti (2011) assert that while human-centered design is highly suitable to improving the quality and utility of an existing product space, it limits the exploration of radical and divergent design trajectories that accompany meaning or technology change, and that such meaning-driven innovation can be potentially driven through design research. Further, when information technologies are viewed as a cultural medium – and software as a design material (Jung & Stolterman, 2011) – Murray (2012) argues that in order to establish new conventions and advance the composition of new forms and potential use scenarios, it may be necessary to think beyond current conventions in interaction design or circumvent users existing perceptions of interface technologies and their affordances. By following concept-driven interaction design, our approach embraces a theorization of existing multi-disciplinary conceptual, historical, and empirical work on creative information seeking within museum and art collections where functionality, form and aesthetics are considered throughout and interpreted holistically.

Given that our approach is concept-driven, our design exploration begins from a theoretical grounding rather than a user-centered approach. However, as elaborated, our key design principles draw from a wealth of empirical user research, such as the work conducted by Skov & Ingwerson (2008) that examine the information seeking behaviors of museum professionals and visitors; the study conducted by Björneborn (2008) that describes human interaction with digital and physical library spaces; empirical research that examines the notion of serendipity within information spaces (McCay-Peet & Toms, 2011) and a series of focus groups and interviews that examine the metaphor of a pathway as a way of providing personalized access of cultural heritage collections to students, scholars, hobbyists and archivists (Clough, Stevenson, & Ford, 2009). Further, the notion of the information flaneur, (Dörk, Carpendale, & Williamson, 2011) a human-centered approach to creative information seeking and a central theme that informs our approach – is in itself a conceptualization drawn from empirical user research.

One of the underlying principles of concept-driven interaction design is that the artifact is deliberately crafted to stand as an argument for its underlying theoretical ideas (Stolterman & Wiberg, 2010). As such, the need to articulate our theoretical underpinnings and design principles as they are instantiated within the working artifact, and how that artifact explores new design spaces in its instantiation, forms an important part of our approach. In IS research and HCI, new designs and interfaces are commonly validated via observation and experimentation with real world users (Greenberg & Buxton, 2008), mostly in the form of usability or user acceptance evaluations. However, Hevner et al. (2004) also propose descriptive and analytical methods as legitimate forms of evaluation that are well suited for innovative or radical designs. These methods present an evaluation of the artifact via an informed argumentation of an artifact’s utility or how it fits within the design space, and in the case of concept-driven interaction design research, how designs are used to augment their underlying theoretical ideas. Descriptive and analytic evaluations are legitimate approaches for evaluating IS artifacts (Aalst & Kumar, 2003) that are also recognized for building IS theory (Gregor, 2006; Jones & Gregor, 2007) in that they link the designed artifact back to its theoretical underpinnings. Venable (2006) describes a similar form of evaluation – the extent to which a design artifact matches its underlying abstract idea, and the extent to which that idea is generalizable to other contexts.

Exploring the Design Challenge and Deriving Design Principles

There are two emerging trends in the way we interact with digital artifacts and their information spaces. The first highlights the expansion of online information spaces due to the increasing availability, cultural significance and audience sentiment of open data (Lew et al., 2013). In the case of museums, it can be seen in the vast digitization of online collections and the use of online media to share knowledge and provide avenues for exploration and meaning-making to take place (Cairns, 2013). The massive scale and federated availability of online collections creates opportunities for audiences to explore these collected works and find new ways to create meaning. This also encourages personal exploration, knowledge sharing and re-appropriation of collections from cultural institutions to their communities of interest. The meaning-making and immersive qualities of interactions with such collections – to the point of “losing track of time” (Fulton, 2009) – calls for new information seeking principles beyond “the utilitarian goals of overcoming information needs, knowledge gaps, uncertainty and problems” (Dörk et al., 2011, p. 1).

The second trend lies in the recognition of pleasure, play (Huizinga, 1971) and aesthetics (Udsen &
Jørgensen, 2005) in human computer interaction. These qualities are explicitly recognized and observed, for example, in our interaction with public interactive cinema displays (Barker, 2010) and reactive table top surfaces (Gaver et al., 2004), reinforcing the idea of *Homo Ludens* (Huizinga, 1971) – humans as innately playful. In recognition of this, Gaver (2002) advocates that our interactions with technology, or a measure of the worth of those interactions, should go beyond preoccupations with utility or task efficiency and embrace approaches that recognize “our playfulness[...] our curiosity, our love of diversion, our explorations, inventions and wonder” (Gaver, 2002, p. 1). These ideas of serendipity and play are explicitly acknowledged as facets of interactions with information retrieval and browsing systems (McCay-Peet & Toms, 2013) – a phenomena observed in our interactions with physical library spaces (Björneborn, 2008), and their digital counterparts (Thudt et al., 2012).

Finally, aesthetic qualities are articulated by the concept of “pliability”. This concept, as defined by Löwgren (2007), refers to both the degree that an interaction facilitates exploration, serendipity, and playfulness in use, and the degree that the interaction feels malleable and tightly coupled in the sense that “the user is drawn into a sense of shaping the digital information with his/her fingertips, even though the actual artifact might employ standard, non-tactile interaction techniques such as mouse, keyboard, and a display monitor” (Löwgren, 2007, p. 71). Löwgren (2007) emphasizes pliability as an innate and sensuous quality that can only be perceived “in the moment” of the interaction: referring to both the tenuous nature of the work of interaction designers as they iteratively assess and “gain a feel” for designing interactions, and the ethereal and fleeting nature of these aesthetic interactions as perceived by end users (Fallman, 2008). Pliability is attained in the prevailing interaction design conventions of iOS devices and applications, which induce highly aesthetic, responsive and animated user experiences through scrolling lists and sliding pages – as well as other swipe gestures – that respond well to the physics of touch-based interaction. Pliability incorporates another dimension which can be realized through direct manipulation as well, one that “considers ‘interface’ and ‘contents [as] not different levels of abstractions but merely two aspects of the same experience” (Löwgren, 2007, p. 79).

**Information Landscapes and Information Flaneurs**

As users are interacting with an ever-increasing array of connected devices that form a meaningful part of their lives (Stolterman et al., 2013; Wiberg, 2012), they also face an increasing abundance of meaningful information. Whether it involves searching for online reviews about a local restaurant, discovering a particularly striking photograph in an online museum collection, or exploring a collection of YouTube videos, consumers’ lives are becoming increasingly enriched and saturated with digital information. Just as Stolterman et al. (2013) frame the notion of *device landscapes* to describe the interwoven nature of our interaction with devices, services and platforms, a similar analogue applies to describe the interconnected, open and expansive *information landscapes* that characterize the way we interact in a world abundant with connected and meaningful digital information.

The idea that information seekers ‘orient’ themselves in an *information landscape* was a concept posited by O’Day and Jeffries (1993) in describing the way library professionals use multiple, interconnected searches to explore topics in an undirected fashion. This closely ties with the notion of *exploratory search* (Marchionini, 2006): the recognition of discovery and learning as a significant part of the search process where information goals may be fuzzy or unknown. In this paper, *information landscapes* are defined as a form of networked knowledge that allows an information seeker to navigate and orient themselves within semantically linked data, commonly manifest via the use of exploratory interfaces and data visualization (Dork, Carpendale, & Williamson, 2011; M Dörk et al., 2011; Ennis-Butler, Hinton, & Whitelaw, 2011; Thudt et al., 2012). In demonstrating a more representational, immersive example of the idea, Andrews et al. (1996) present an information landscape as a 3-dimensional visualization of hyperlinked data-entities in which the viewer can orient themselves within an expansive structure. A similar approach was adopted by Ruffaldi et al. (2008) in presenting cultural heritage content, where the metaphor of an *information landscape* was fruitfully realized in its depiction of linked knowledge, textual data and rich media through the use of, 3-dimensional elements and deep visual perspective.

Taking into the account the exploratory mindset of the information seeker, or the expansive *information landscapes* that they may immerse themselves in, we begin our exposition of the concept by drawing analogies between the information landscapes of the modern Web to the physical world that we live in. We also describe the exploratory mindset of the *information flaneur* (M Dörk et al., 2011): a literal
personification of a creative, curious and critical information seeker that likens the information seeking experience on the Web to that of an explorer of a large, modern city. From this we draw on the notion of a *pathway* as a mean of traversing these information spaces.

Murray (2012) recognizes our allure to physical geography and the natural path-finding instincts of our ancestors, and introduces the metaphor of a landscape as a useful notion for framing interaction design conventions that elicit navigable, open and connected spaces. Murray argues that the way we view the world as a landscape is manifest through our use of language: the “information spaces” of the “World Wide Web”; mastering a “domain” or “expanse” of knowledge; viewing “landmark” works, “crossing discipline boundaries”. Landscapes are therefore a fundamental framework that humans use to make sense of the world, both in natural spatial and non-spatial ways. Following from this, Dörk et al. (2011) argue that the design of navigable spaces should establish conventions that determine and consistently uphold rules for spatial interaction; these can range from the consistency of a multi-level menu presented on a news website, the use of “breadcrumbs” to show paths traversed, and the visual and semantic distinction between nodes (objects) and paths (relationships) that are shown in many data visualisations.

One of the most readily observed cases of technology-augmented creative exploration takes place in the form of the 3D games and in cartographic software. As these depict environments that are attuned with our innate path-finding instincts (Murray, 2012), technology products such as Google Earth and Google Street View shift the meaning behind mapping and cartography software from primarily functional tools for navigation and way-finding to interfaces that drive more leisurely pursuits of curious exploration. For example, using integrated and expansive 3-dimensional displays of street and aerial photography, the ability to explore foreign cities and landscapes using actual imagery has induced cartographic and emotional experiences in the form of mediated tourism (Jensen, 2010). A similar drive for curious exploration, at least within the realm of cartography, is reflected in a concept design in the form of a coffee table that displays drifting aerial imagery (Gaver et al., 2004) where, for some users, it was used to explore new areas or provide aerial imagery of places that were meaningful to them. Other users, however, in an almost futile interaction with the technology, simply “[let it] wander and see what happens” (Gaver et al., 2004, p. 896).

The analogical notion of a *landscape* is illuminated against the more restrictive organizing framework of a *container*. Whereas landscapes are fluid, expansive and open, containers are discrete, restrictive and categorical. These different interfaces highlight different qualities that shape the navigational experience of online collections: landscapes employ boundaries, signposts and markers to denote meaning – a quality commonly attributed to data visualizations and topographical maps but also attributed to 3D games and non-linear narratives, whereas containers employ labels and nesting to employ a sense of position and hierarchy, such as that typically seen within a menu bar or within museum classification systems, see Figure 1.

Dörk et al. (2011) argue the need for new information seeking metaphors that characterize a particular kind of interaction that is primarily based on exploration, serendipity and discovery – one that is under-represented by existing interaction models and methodologies that primarily focus on externally defined user goals and task completion efficiency. In particular, these authors draw parallels between the immersive qualities of the interwoven streetscapes of modern cities and the increasingly linked and enriched information spaces of the modern Web and propose the *information flaneur*: a persona that depicts the curious, creative and critical information seeker. Personas are commonly employed by interaction designers to characterize various stakeholders that may use a product (Nielsen, 2013). Hence, the curious, creative and critical information seeker understanding of information seeking is best conveyed via imagery rather than prescription. This is in antithesis to the personas traditionally used in use case analysis in IS that characterizes goal-driven interactions with computing, or the attentive search agent who craves relevant information recall but demands precise results. The *information flaneur*, on the other hand, offers an almost recreational perspective of human–computer interaction: namely that of a wandering, curious information seeker. As Dörk et al. (2011, p. 3) put it: “We are particularly interested in his exploratory mindset. In order to experience the city, the flaneur does not methodically navigate streets, checking each edifice like a building inspector in search of code violations. Nor does the flaneur hastily interrogate each city-dweller, like a police officer in search of a thief. Because the flaneur does not accurately scrutinize everything that crosses his path, he is able to sense what city life is about. The flaneur is the embodiment of exploration and serendipity, while the police officer and building inspector..."
personify traditional search and browsing.”

Figure 1. Landscapes in the San Francisco Museum of Modern Art (left); Containers in the Powerhouse Museum Sydney, (right).

In addition to describing the explorative potential of emerging information spaces, Dörk et al. (2011) also advocate interaction design conventions that promote exploration and curiosity. To entice the perceptual qualities of the *information flaneur*, they posit the use of techniques such as similarity-based suggestions and visual information surrogates (Greene et al., 2000). The authors also advocate the use of *visual momentum*, described as the way interfaces provide a smooth transition from one context (or view) to another. Interfaces that exhibit high levels of visual momentum require less cognitive effort to comprehend display changes, and employ techniques such as animated transitions, detail-on-demands and contextual, integrated zoomable views (Dörk et al., 2012).

According to McCay-Peet & Toms (2013) serendipitous interfaces should enable connections, introduce the unexpected, present variety, trigger divergences and induce curiosity. These principles were adopted by Ennis-Butler et al. (2011) in their work on exploratory data visualisations for museum collections. The authors recognize data itself as cultural medium and employ ideas of play as a way of engaging with complex data (Hinton & Whitelaw, 2010; Whitelaw, 2012). Following the museological notions of context and connectedness (Hoptman, 1992; Schweibenz, 1998), Whitelaw (2012) argues that the value that lies within cultural collections can be better harnessed by designing “generous” interfaces that promote immersive browsable views, prominent visual imagery of primary content, and depictions of context and relationships. These views parallel the design principles developed and empirically tested by McCay-Peet and Toms (2013): principles that allude to the perceptual needs of the *information flaneur*.

**Pathways as a Mechanism to Semantically Structure Content and as a Metaphor for Creative Exploration**

The fit between these design principles and cognitive user models has been examined in research that investigates creative information seeking behaviors in online museum collections. Skov (2009) found that online visitors demonstrated exploratory behaviors such as serendipity and, when finding the unexpected, exhibited meaning making qualities, i.e. following paths and making implicit connections between objects. The research stated that such users sought highly visual experiences, such as the use of large and prominent photographs, and noted that exploratory behaviors were featured amongst a broader pattern of information seeking needs (Skov & Ingwersen, 2008). Goodale et al. (2012) conceptualize the *pathway* as a guiding metaphor to characterize the design of digital artifacts that support creative and divergent
exploration of cultural data-sets. Following an empirical survey that examined information seeking requirements and behaviors of expert and non-expert users of museum collections, they elaborate the concept of pathways in two distinct dimensions. Firstly, pathways provide a mechanism that affords creative, non-linear interaction within a collection: a pathway can be interpreted as a search history, an augmented reality or an information seeking journey, suggesting that they can be used to guide users through collections. Secondly, pathways support learning by enacting meaningful structure and context to museum collections: pathways are interpreted as linked metadata that enables learning and meaning-making to take place.

The above characterization of pathways serves as the overarching interaction design principle for presenting and navigating digital art collections. In this design, we account for the dual meaning of pathways as a metaphor for creative exploration within information spaces to support non-linear interaction and information seeking behaviors and as a mechanism that semantically structures content to support connectedness, meaning making and context. The former has been described in the context of a broader theoretical understanding of interaction design; the historical concept of the “virtual museum”; emerging models of information seeking that incorporate elements of play and creativity; along with empirical research that examines design principles of serendipitous interfaces and the way users interact with museum collections. This can be summarized in the following design guidelines and principles: the principles of playfulness and serendipity; designing for exploration; pliability as an experiential quality of sustained interaction; the use of visual momentum; and the use of interfaces that employ high amounts of visual imagery and similarity-based recommendations. The latter meaning of pathways will be further discussed in the next section where we describe the working artifact and its interaction design as well as the mathematical foundations and algorithms that drive its pathways.

Building a Working Artifact and Evaluating the Design Principles

In the following we present A Place for Art, the working artifact, which has been developed by following the design principles identified above. A Place for Art showcases a collection of contemporary and Australian indigenous works from the University of Wollongong’s Art Collection. It is a digitized companion piece to the print publication of the same name published by the University of Wollongong Press (Lawson, 2012). A Place for Art provides access to 77 works and accompanying short essay pieces that feature the history of the collection and significance to its local region.

Generating Pathways

Pathways in A Place for Art are represented by formal concepts: conceptual structures that are induced by Formal Concept Analysis (Wille & Ganter, 1999). With its ability to create knowledge structures that fall outside of traditionally culturally biased frameworks (Cairns, 2013; Weinberger, 2005) and its close connection to the philosophical logic of human thought (Wille, 2005), Formal Concept Analysis is an effective way of creating context and meaning within museum collections by highlighting the implicit relationships among objects, particularly as museums are increasingly turning to alternate and unstructured sources of knowledge, such as social tagging (Trant, 2009). In describing Formal Concept Analysis, its mathematics and its ability to articulate human thought and communication, we now illustrate how pathways are generated in A Place for Art and how they are used to represent a reconstruction of its major themes.

Formal Concept Analysis was developed in the early 1980s as a mathematization of the human cognitive constructs of concepts and concept hierarchies (Wille, 2009). Concepts are understood as basic units of thought shaped by observations of existing phenomena and “formed in dynamic processes within social and cultural environments” (Wille, 2005, p. 2). According to its philosophical definition (Wille, 2005), a concept is composed of a set of objects as its extension, and all attributes, properties and meanings that apply to those objects as its intension. As an example, if one considers the idea of “works that depict heavy industry and the Illawarra” (its intension), which we derived from the text analysis of the printed catalogue, there are 7 paintings (its extension) in the collection which have these attributes (see Table 1); a concept is therefore defined as the simultaneous perception of its intension and extension – i.e., the compositional qualities of those paintings (as attributes) and the actual paintings (as objects) defined via those attributes. In Formal Concept Analysis, concepts are mathematized as formal concepts defined as a pair \((G, M)\) where \(G\) and \(M\) respectively correspond to the formal concepts’ set of objects \(G\) (its extension)
and the attributes that describe those objects $M$ (its intension).

Concepts are never perceived in isolation, but in the context of existing phenomena. By interpreting concepts in context, one can derive implications and perceive their relational and spatial properties to other concepts. For the purposes of interpreting works in *A Place for Art*, we consider groups of artworks that share equivalences as concepts that are a part of the 77 works that compose its collection, its context. In Formal Concept Analysis, the context is mathematized as a formal context defined as a $K(G, M, I)$ where $G$ and $M$ respectively describe its set of objects and attributes and $I$ describes the associations between them. Formally, $I \subseteq G \times M$ is a binary relation where $(g, m) \in I$ is read "object $g$ has attribute $m$". Hence, a formal context, in its most basic form, can be understood as a structure that describes all objects and the sets of attributes that are applied to those objects.

In constructing the formal context for *A Place for Art*, we examined key themes from the print publication “A Place for Art” essay (Lawson, 2012), along with key iconographical elements and visual characteristics from the works depicted. The essay presented a narrative that describes the history and the significance of the collection, and identifies key concepts, such as the way the works depict the industrial life of the city of Wollongong, or the natural beauty of the region’s (the Illawarra) escarpment. We then classified the themes according to several other dimensions – not made explicit from the essay – including the type of work, its medium, visual characteristics, imagery, tone, color and iconography.

<table>
<thead>
<tr>
<th>Table 1. A sample of formal concepts from <em>A Place for Art</em></th>
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<tbody>
<tr>
<td><strong>Formal concept, expressed in natural language</strong></td>
</tr>
<tr>
<td>paintings that depict the Illawarra</td>
</tr>
<tr>
<td>works that evoke identity issues and social critique</td>
</tr>
<tr>
<td>surreal works that depict animal imagery</td>
</tr>
<tr>
<td>vibrant and abstract paintings</td>
</tr>
<tr>
<td>intricate works that depict nature</td>
</tr>
<tr>
<td>vibrant works that evoke a sense of calm</td>
</tr>
<tr>
<td>works that depict heavy industry and the Illawarra</td>
</tr>
</tbody>
</table>

A valuable layer of meaning is added when concepts are perceived in context. One way of inferring meaning is by deriving attribute implications. These implications provide the assertion that “within a given context, if all objects with $X$ attributes also possess $Y$ attributes, then $X$ infers $Y$”. Applying this form of data mining gives the ability to gain insights into the implicit relationships and phenomena within the collection. In *A Place for Art*, it infers that, for example, *all works that depict natural landscapes are painted with coarse brush strokes*, or that all the depictions of *heavy industry* in the *A Place for Art* collection also take place in the Illawarra.

Using the latter assertion as an example, these attribute implications are formed by the way formal concepts are constructed: for a formal concept $(G, M)$, that has an attribute set $M = \{\text{heavy industry}\}$, let $G$ be composed of all objects that possess $M$, giving the result of:

$$G = \{\text{“Waiting, Port Kembla”, “Foundry Men”, “Wollongong Steel Works BHP”, ... }\}$$

Now let $M$ be all attributes common to objects in $G$, giving the result of:

$$M = \{\text{heavy industry}, \text{the Illawarra}\}$$

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1 To simplify this example, the titles of the artworks are shown here. For brevity, only 3 out of the 7 titles are shown.
$G$ and $M$ are then combined as $(G, M)$ to create a closed concept. The additional attributes that were derived from this operation give rise to their implication, in this case, ‘heavy industry’ $\rightarrow$ ‘the Illawarra’. In *A Place for Art*, formal concepts are computed using a specific algorithm, the PCbO algorithm (Krajca et al., 2008). Within its context of its 77 artworks, there are a total of 330 formal concepts, 7 of these formal concepts expressed in natural language are shown in Table 1. By deriving clusters from data and inferring association rules, formal concepts provide the mathematical realization of – what we call – a convergence: the way a group of otherwise disparate works of art are represented as a meaningful whole.

*A Place for Art* also employs purpose built algorithms for describing concepts in natural language. The examples shown here and in Table 1 are direct outputs generated from these algorithms. When a formal concept is expressed in natural language, the algorithm takes its intension – i.e., its set of attributes – and orders them based on their semantic qualifiers and parts of speech, such as whether they depict the work itself (‘painting’, ‘screenprint’, etc.), are adjectival (‘surreal’, ‘vibrant’, etc.) or are otherwise appended as clause fragments (‘identity issues’, ‘a sense of calm’, etc.). Using basic principles of grammar and sentence construction, these attributes are then conjoined to produce a statement. The algorithms also take into consideration whether the natural language statement should be expressed in a singular or plural form, given that, according to the principles of Formal Concept Analysis, individual objects are also formal concepts. These natural language statements are used to convey the semantic meaning of convergences as human-readable, narrative-like statements.

Meaning is further conveyed when concepts are observed in relation to one another. Concepts are inherently spatial and relational, as connections of concepts are networked to create a concept lattice (Wille, 2009) or are spatially conveyed via a measure of their concept similarity and distance. One common method of constructing a knowledge space in Formal Concept Analysis is via the exploitation of the subconcept/superconcept relationship, i.e., the idea that certain formal concepts can be more specific or more general than other formal concepts. Within a context, the complete set of formal concepts – ordered by this relationship – induces a concept hierarchy – an implicitly structured collation of human knowledge that can be represented visually as a concept lattice.

![Figure 2. A concept lattice (as a line diagram) showing a small selection of artworks from *A Place for Art*.](image)

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2 This excludes all formal concepts with a singular extent since they describe a single object.
Following the example in Figure 2, the concept *abstract paintings with geometric patterns and coarse brush strokes* – depicted by the artwork titled *Solar Boat* as it appears bottom-right in the concept lattice – is a subconcept of *abstract paintings with geometric patterns* – that also includes the artwork *Port Kembla Landscape*, appearing to its top-right – which in turn is also subconcept of both *abstract paintings* and *abstract works with geometric patterns*. When these concepts are presented in a concept lattice, subconcepts appear below superconcepts. In Formal Concept Analysis, a formal concept \((A, B)\) is considered to be a subconcept of \((C, D)\) (expressed as \((A, B) < (C, D)\)) if \(A \subseteq C\) and \(B \supseteq D\). Likewise, a formal concept \((A, B)\) is considered to be a superconcept of \((C, D)\) (expressed as \((A, B) > (C, D)\)) if \(A \supseteq C\) and \(B \subseteq D\).

Relations between concepts can also be understood in terms of conceptual neighbors – concepts that are immediately more general or more specific to one another within the concept hierarchy. A concept \((A, B)\) is said to be the lower neighbor, of concept \((C, D)\) if \((A, B) < (C, D)\) such that there is no concept \((E, F)\) that gives rise to \((A, B) < (E, F) < (C, D)\). Likewise a concept \((A, B)\) is said to be the upper neighbor, of concept \((C, D)\) if \((A, B) > (C, D)\) such that there is no concept \((E, F)\) that gives rise to \((A, B) > (E, F) > (C, D)\).

Following the running example, the concepts *abstract paintings with geometric patterns and coarse brush strokes*, *abstract paintings* and *abstract works with geometric patterns* are all conceptual neighbors of *abstract paintings with geometric patterns*.

Concepts can also be related in terms of similarity: i.e., certain concepts can be considered conceptually similar based on sharing some common objects and attributes, with the mathematics of such described in Formica (2008). Furthermore, concept similarity provides a fast approximation for identifying a concept’s neighbors. In Table 2, for example, for the formal concept *abstract paintings with geometric patterns*, its immediate lower neighbor *vibrant and abstract paintings with geometric patterns* is identified as its most similar concept. It is also partially similar to the more distant *energetic and abstract paintings with geometric patterns*, more so than the notionally relevant *paintings that depict the Illawarra* and the almost irrelevant *works that depict animal imagery*. These concept similarity metrics are also valid for comparing object-to-concept as well as concept-to-concept relationships, since, according to the mathematics of Formal Concept Analysis, formal concepts can represent individual objects called *object concepts*. For instance, consider the print *‘Illawarra Flame Tree and Bowerbird’* (Figure 3) which is, according to the natural language description of its object concept, “an intricate and vibrant print that depicts the Illawarra and has red and blue tones.” Using the concept similarity metrics described above, we can observe the multiplicity of contexts that this object can be interpreted in, and determine which concepts are ‘most’ similar to the artwork (shown below in Table 3).

<table>
<thead>
<tr>
<th>Table 2. Concepts similar to <em>abstract paintings with geometric patterns</em></th>
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</thead>
<tbody>
<tr>
<td><strong>Formal concept, expressed in natural language</strong></td>
</tr>
<tr>
<td>vibrant and abstract paintings with geometric patterns</td>
</tr>
<tr>
<td>energetic and abstract paintings with geometric patterns</td>
</tr>
<tr>
<td>abstract paintings</td>
</tr>
<tr>
<td>energetic and vibrant paintings</td>
</tr>
<tr>
<td>paintings that depict the Illawarra</td>
</tr>
<tr>
<td>works that depict animal imagery</td>
</tr>
</tbody>
</table>

Examining these objects in these contexts and ordering them by relevance gives the ability to induce new objects and draw equivalencies between them. This provides the basis of how *divergences* work in *A Place for Art*. Divergent exploration is based on the idea that every turning point within the collection should infer new objects and enlighten new connections. Hence, divergences have two design criteria: a) they should infer new objects based on similarity of an object of interest and b) the resulting pathways should always infer new objects that have not yet been presented previously by prior convergences. This
approach avoids repetition and circularity navigating the information space, where the sum of divergences affords a gradual unveiling of the collection by highlighting new works of interest.

Figure 3. ‘Illawarra Flame Tree and Bowerbird’

<table>
<thead>
<tr>
<th>Formal concept, expressed in natural language</th>
<th>Similarity Score</th>
<th>No. of objects</th>
</tr>
</thead>
<tbody>
<tr>
<td>intricate prints that depict animal imagery and nature</td>
<td>0.50</td>
<td>2</td>
</tr>
<tr>
<td>works that depict animal imagery and have red tones</td>
<td>0.38</td>
<td>2</td>
</tr>
<tr>
<td>intricate works that depict nature</td>
<td>0.21</td>
<td>3</td>
</tr>
<tr>
<td>works that have blue tones</td>
<td>0.13</td>
<td>8</td>
</tr>
<tr>
<td>works that depict animal imagery</td>
<td>0.11</td>
<td>11</td>
</tr>
<tr>
<td>vibrant works</td>
<td>0.08</td>
<td>23</td>
</tr>
</tbody>
</table>

When considering what objects to show in a divergence, firstly all the other objects represented by the pivot point are determined, along with the total set of objects depicted in prior convergences. Based on the object depicted in its pivot point, an object concept is constructed, in which a set of formal concepts containing that object are retrieved. Using concept similarity metrics, the formal concept that is selected is the one that has the highest similarity score containing objects not part of a prior set of convergences. These new objects are then reconstructed as a formal concept, so that any additional attributes are implied from this reduced set, which is then presented as an adjoining pathway from the pivot point.

The mathematization of the convergent-divergent paradigm of navigation and its implementation in A Place for Art highlight the spatial properties of its interaction and of its underlying conceptual structures. These structures recognize the inherently polyvalent nature of knowledge and interpretation that surrounds museum objects (Cairns, 2013), and, through the convergent-divergent paradigm, A Place for Art intends to afford creative exploration of these structures in a non-didactic way.

The convergent-divergent paradigm is also supported by the theory and philosophy of Formal Concept Analysis in two ways. Formal concepts – just like the human concepts they are modeled on – express subjectivity and emotions (Wille, 2005). In the context of museum collections, this provides the ability to model human meaning and thought in the form of sentiments and conjectures; within the A Place for Art, the idea that certain works have ‘warm tones’ or ‘evokes a sense of calm’. It also offers a way of creating inferences and structures from these conjectures without their explicit encoding in other formal knowledge representation schemas.
The second implication concerns the relational qualities of the conceptual structure, a quality best observed from the concept lattice (Figure 2). Wille (1999) introduces the notion of conceptual landscapes as a metaphor to describe the inherently spatial properties of human knowledge, drawing parallels to Murray’s (2012) landscape paradigm. Whereas Murray’s perspective refers to spatial qualities of navigating information spaces, Wille’s conceptual landscapes describe the way humans produce, communicate and consume knowledge. Yet, like Murray, Wille alludes to the metaphorical adoption of landscape motifs that dictate the way humans interact with information spaces, and shares the view that computers are a medium, rather than a container for the storage and display of data. He argues “The idea of a landscape is becoming increasingly influential in the field of knowledge representation and processing. Especially, the frequently used term of “navigation” suggests this idea is becoming a leading metaphor. That view is also supported by the development of computers as a medium. This development shows that it is time for explicating the pragmatic landscape paradigm for knowledge processing” (Wille, 1999, his emphasis).

From this proposition, Wille defines the practice and discipline of Conceptual Knowledge Processing (Eklund & Wille, 2007; Wille, 1999, 2006) as a set of techniques that make use of a variety of conceptual structures to augment human activities in knowledge representation, processing and communication. Within this framework, Wille defines the act of **identification** – the positioning and contextualization of objects, concepts or data elements in relation to other objects, concepts or data elements and **exploration** – understood as the act of seeking without a goal, or where the item in question is vague or not well known. The two acts of identification and exploration have strong correspondences to the convergent-divergent approach to navigation which implements the earlier identified design principles and is described in detail in the next subsection.

![surreal works that depict dreamlike imagery](image)

**Figure 4. A pathway in A Place for Art.**

**Navigating Pathways**

Pathways are visibly and tangibly represented in A Place for Art. They are depicted as horizontally lateral galleries of images that represent thematic concepts derived from the meta-data of the artworks as described above. A pathway in A Place for Art group works into semantically similar themes. Figure 4 provides an example of a pathway entitled surreal works that depict dreamlike imagery. As their imagery
occupies most of the available screen space, these pathways follow the design principles of serendipitous (McCay-Peet & Toms, 2013) and “generous” interfaces (Whitelaw, 2012) via their emphasis of primary content and visual surrogates. Above each pathway is a title that remains fixed to the top of the screen describing the thematic characteristics of the shown artworks. Although users can swipe laterally to explore the works within the pathway, the title is fixed and always remains in view.

Pathways present and contextualize artworks so that a user, the information flaneur, can view their common and shared characteristics, and in doing so, learn about the themes that are present within the collection. These pathways group objects into non-exclusive, non-categorical clusters based on the formal concepts identified by Formal Concept Analysis. Each formal concept depicts a unit of thought dictated by its objects, in this case, a set of artworks, and attributes, in this case, the shared characteristics and themes of the artworks. Formal concepts represent meaningful fragments of the collection, and pathways afford the ability to view objects in the multiplicity of their contexts.

In Figure 4, the work *Baa Baa Black Sheep* is depicted as part of a series of surreal works that depict dreamlike imagery, and is comparable to the work *Bush Rat*. However, the work can also be found if we were exploring black and white works or as part of a similar set of surreal works that depict animal imagery. Similarly, *Bush Rat*, also shown in Figure 4, is one such work that depicts animal imagery, along with many works that depict natural and organic themes. Providing meaningful and overlapping contexts to a group of objects is realized as a convergence, a concept we introduced above.

Following the above theorization of pathways, convergences follow the design principle of pathways as mechanisms that semantically structure content by collating works into non-exclusive concepts and enacting meaningful context to clusters of artworks. However, as a means of creative exploration within information spaces – *A Place for Art* also provides the ability for its users to “branch” and create new pathways by revealing more works and explore the collection by highlighting works of interest. This describes the symmetrical affordance of a divergence. Within the interface, divergences are implemented in the form of gesture-based interactions and direct manipulation of the pathway structure itself. Double-tapping on an artwork pivots a new pathway (the divergence) that shows a new set of works conceptually similar to the work that was tapped on (the pivot point), that are in turn, semantically similar to the previous pathway. In order to convey this state change to the user, *A Place for Art* animates the transition such that the artwork appears to be physically ‘displaced’ and rotated from its previous path, where it is then joined to a new path that reveals a new convergence. Animation and contiguous forms are used to convey divergences and help users form mental models of state changes.

Figure 5 shows a divergence, where double-tapping on the artwork, *Crocodile* (its pivot point), displaces it from the previous path (a divergence) and then ‘joins’ it to a new path that places that work in a new context (a new convergence). This divergence removes *Crocodile* from its old context: works by indigenous artists, and places it into a new but similar context intricate works that depict nature, that introduce more artworks that follow a renewed trajectory. This displacement conveys a shift from one context to another, as new works are shown that provide opportunities for further divergences.

The interaction design of *A Place for Art* explicitly conveys a spatial and conceptual transition across an information space. Through the use of explicit visual momentum (Dörk et al. 2011) a spatial transition is achieved by the use of animations that depict the work being physically displaced from the old context to the new. Similarly, the conceptual shift from one context to another is conveyed via the use of natural language statements that describe the two intersecting pathways: this highlights the implicit relations between the two and the overlapping contexts of a particular artwork of interest.

Just as users can “branch” and create new pathway structures based on artworks of interest, users can also “back-track” and traverse their navigation history: allowing the option to rollback prior divergences and create new paths at different pivot points. As users create more divergences and unfold different parts of the structure, they can thematically traverse the collection in a non-linear, self-determined manner. Users can back-track any number of paths that they have previously created, and the state of their path history persists even if the user closes and re-opens the app. Likewise, extensive analytics tracking has been implemented that records the frequency of artworks viewed and the content of each path, so that the system could infer, for example, how users interacted with the path structure, whether they were selective in the works chosen for new path creation and whether users preferred following specific paths over others in the collection.
Figure 5. A divergence in *A Place for Art*.

Over time, as users create more divergences that reveal new content based on specific objects of interest and as they shift their conceptual view of the collection, they uncover implicit phenomena that connect the objects and gain a sense of the thematic concepts that compose the collection.

Figure 6. Navigation in *A Place for Art*: an example of six divergences
This is shown in Figure 6, where a series of six divergences depicts the movement through the conceptual space from “works that depict animal imagery” to “works that depict nature and have earth tones.” As the data that drive these pathways are in part derived from key themes identified from the print publication’s essay, *A Place for Art* (the iPad app) represents a reconstruction of that essay where users can interact with the collection and the shared meanings behind the works in a non-linear manner.

**The experiential quality of the interaction design and navigating pathways**

The experiential and aesthetic qualities of interacting with and navigating *A Place for Art* are realized through the design principle of *pliability* (Fallman, 2008; Löwgren, 2007). The pliable qualities of *A Place for Art* are achieved by following interaction design conventions that are common in iOS applications, such as the convention of presenting content as scrolling lists, in our case horizontally oriented scrolling lists of art works (see Figures 4 and 5). Users can “slide” pathways that spawn a sense of aesthetic and creative exploration: a flick of the finger induces a dizzying flurry of works, a careful nudging or ‘thumbing’ of the works warrants closer inspection and examination. The pathway structure itself can be directly manipulated to browse the collection and discover more works. This sense of direct manipulation with the content at hand, the visual surrogates of the images and the close connection between action and outcome engender one dimension of pliability. However, in a more nuanced elaboration of pliability, *A Place for Art* also encompasses a sense of direct manipulation where interface and contents are encountered in concert (Löwgren, 2007). This dimension of direct manipulation engenders the sense that the user is directly manipulating and engaging with the contents and structure of the collection itself.

The way content is presented in *A Place for Art* is rather non-didactic and yet – to some extent – constrained given that both its form and data structures are based on the inherently semantic construct of pathways. However, the design affords the ability for the *information flaneur* to interact with the pathway structure in order manipulate the data and create their own views into the collection. The use of animations to depict divergences or roll-back prior divergences serves a dual purpose: it helps users form mental models of the semantic changes that are occurring within the information space, i.e., by visually conveying animations that depict “branching” as it places a pivoting object in a new context. It also endeavors to cause a sense of direct, visuo-tactile interaction with the path structure itself – an interaction design approach that conflates interface and content where action and response are tightly coupled.

**Conclusion – A Design Theory**

Following the design science research approach proposed by Åkesson et al. (2010) and concept-driven interaction design (Stolterman & Wiberg, 2010), *A Place for Art* is a design exploration on the way new interaction approaches can be used to convey meaning and context to museum collections in the form of a working artifact. It follows from museological perspectives concerning the way the digital medium can be used to express connections between works of art and the multiplicity of their contexts of interpretation. As a companion piece to the print publication of the same name, *A Place for Art* provides a means for visitors to interact with the collection in a divergent and non-linear way. Our work provides a design theory for the interactive presentation and navigation of digital art collections which follows Gregor and Jones’ (Jones & Gregor, 2007) criteria for a design theory. This design theory is summarized in Table 4.

Pathways are described as a way of navigating information landscapes as both a metaphor for creative exploration and as a mechanism to semantically structure content. The concept of pathways as a metaphor for creative exploration is supported by a synthesis of literature that examines creative information seeking within information spaces and leads to the derivation of principles for designing exploratory interfaces. These principles are embodied in the interaction design of *A Place for Art* and its aesthetics of interaction are further elaborated via the concept of pliability. Convergences are employed as a way of ascribing meaning to groups of conceptually related artworks, and divergences are used to entice further connections and promote discoverability. The concept of pathways as a mechanism that semantically structures content was established via the implementation of the convergence-divergence paradigm, in which its knowledge structures were induced by the mathematics of Formal Concept Analysis. The technique has strong salience to the philosophical logic of human thought and affords the ability to induce and structure knowledge from subjective and emotional attributes.
A Place for Art, as a concept design, highlights how pathways can be used to afford new interaction approaches for navigating conceptually enriched collections. This approach incorporates emergent perspectives on creative information seeking within information spaces, and embraces the metaphor of landscapes: unified in theories concerning the spatial nature of digital artifacts (Murray 2012) and of knowledge itself (Wille 2006).

The construction of the knowledge context for A Place for Art was based on a relatively small selection of works that were well known and easily interpreted. A Place for Art has so far been evaluated through a thorough conceptual and analytical assessment (Aalst & Kumar, 2003; Alan R. Hevner et al., 2004), the next step is to submit the artifact for empirical evaluation (Pries-Heje & Baskerville, 2008; Venable,

<table>
<thead>
<tr>
<th>Component</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>Purpose and scope</td>
<td>The aim is to develop new interaction design approaches to convey meaning and context in museum collections to express connections between works of art and the multiplicity of their contexts of interpretation.</td>
</tr>
<tr>
<td>Constructs</td>
<td>The entities of interest in the theory are provided as metaphors such as pathways, the notion of the information landscape and the persona of the information flaneur.</td>
</tr>
<tr>
<td>Principles of form and function</td>
<td>The dual meaning of pathways as a metaphor for creative exploration within information spaces to support non-linear interaction and information seeking behaviors and as a mechanism that semantically structures content presents the overarching principle of form and function.</td>
</tr>
<tr>
<td>Artifact mutability</td>
<td>Artifact mutability is addressed: the theory is based on a number of generic design principles that can be instantiated differently for art collections varying in size and thematic complexity (as suggested in the concluding remark).</td>
</tr>
<tr>
<td>Testable propositions</td>
<td>It is claimed that the approach raises the potential of how gesture-based interfaces and novel interaction design approaches can be demonstrated to provide non-linear information seeking experiences of art collections as compared to more conventional affordances for online museums, such as search and faceted browsing, and non-digital mediums, such as physical exhibitions and print publications.</td>
</tr>
<tr>
<td>Justificatory knowledge</td>
<td>The underlying knowledge and theory based on museological perspectives on the way digital media can be used and on new insights into interaction design for digital artifacts and their information spaces lead to a number of design principles, namely those of playfulness, serendipity, pliability, similarity-based suggestions, information surrogates, visual momentum, and generosity.</td>
</tr>
<tr>
<td>Principles of implementation</td>
<td>A description of processes for implementing the theory is provided in the form of Formal Concept Analysis, the convergence-divergence paradigm, and pliable design conventions inspired by iOS based artifacts.</td>
</tr>
<tr>
<td>Expository instantiation</td>
<td>The artifact has been physically implemented as A Place for Art that can assist in representing the theory both as an expository device and for the purposes of testing.</td>
</tr>
</tbody>
</table>
2006). Future work will then comprise the application and appraisal of the design principles on larger and more complex art collections.

**References**


