Twin Worlds: Augmenting, Evaluating, and Studying Three-Dimensional Digital Cities and Their Evolving Communities

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Abstract. New approaches and tools are required to inform the design and implementation of 3-dimensional (3-D) digital cities and to steer the growth of their virtual communities. This paper argues to apply information visualization techniques and to utilize *Twin Worlds* – pairs of virtual worlds in which one world is devoted to visualize user interaction data collected in the other world – to augment, evaluate, and research the digital cities of tomorrow. The approach is exemplified by means of an abstract scholarly digital city: A 3-D collaborative *Memory Palace* – a shared resource of online documents (web pages, papers, images, videos, software demos) for faculty and students at the School of Library and Information Science at Indiana University – and its twin, *Mirror Garden* – a second 3-D world that visualizes user interaction data collected in the *Memory Palace*.

1 Introduction

Today, digital cities (DCs) and community networks are developed all over the world (Ishida & Isbister, 2000). They are used for orientation, education, job hunting, urban planning, disaster management, and social welfare etc.. They can be seen as a local social information structure, a communication medium, a tool to improve local democracy and participation, a practical resource to organize every day life, or a space in which to experience and experiment with cyberspace (van den Besselaar et al., 2000).

Most DCs utilize the World Wide Web – an elaborate, connected network of documents – and augment it with diverse synchronous and asynchronous communication facilities such as chat, email, message boards, etc. However, in this environment, people have to chat constantly to be visible to others. Elements like word choice, text format and layout, and timing replace nonverbal aspects of communication such as gestures, facial expressions, proximity, etc. commonly found in face-to-face interaction. Still, despite these “replacement” methods, web surfing remains a lonely activity – one is unaware of other users since they and their “digital footsteps” remain mostly invisible over the web.

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However, what people attract most are people. Advances in computer and networking technologies fueled the rapid growth of 3-D browser systems that enable the creation of compelling, multi-modal, multi-user, navigable, collaborative virtual environments in 3-D that are inhabited by avatars (graphical icons acting as placeholders for human users in a cyberspace system), and provide means for interacting with the objects in the environment, with embedded information sources and services, or with other users and visitors of the environment. Several DCs, e.g., *Virtual Helsinki, Digital City Kyoto, Virtual Los Angeles*, and *Virtual Bremen* make extensive use of 3-D virtual real estate, and others have experimented with it, e.g., *The Digital City Amsterdam*. (URL's are in the references list)

Today's DCs have very diverse goals and serve the similarly wide-ranging needs of their communities. Surprisingly little is known for most of them. Research on virtual cities (or virtual worlds or virtual environments)[1] and their communities is just beginning to emerge (Kim, 2000; Preece, 2000). Often, techniques are borrowed from various disciplines like sociology, psychology, anthropology, ethnography, groupware, communication science, and geography (mapping, organizing spatial data), to name just a few. However, 3-D virtual worlds have unique features such as 3-D user interaction, multi-modality, usage of avatars, etc. that are hard to address with combinations of existing techniques. Novel approaches and tools are required to inform the design and implementation of 3-D digital cities and to steer the growth of their virtual communities.

Heim (1997) and Jakobsson (1999) argue that virtual worlds (VWs) are fundamentally different from our real world and that the underlying principle for VWs – the interaction among its users – should become the foundation for a new theoretical perspective on VW design (Holmström & Jakobsson, 2001). We argue that tracking and visualization of user interaction data collected in 3-D can be seen as an enabling tool to guide users, to evaluate and optimize user interactions in 3-D, and to research VWs.

The paper starts with an introduction and discussion of 3-D collaborative information visualizations that utilize 3-D online browser technology. Subsequently, we introduce the approach of twin worlds and instantiate it in terms of a scholarly digital city – a shared resource of online documents for faculty and students at the School of Library and Information Science (SLIS) at Indiana University and its twin world, which visualizes user interaction data. We conclude with a discussion of the approach.

2 Collaborative Information Visualizations & Twin Worlds

Information visualization techniques (Card et al., 1999; Chen, 1999; Ware, 1999; Spence, 2000; Dodge & Kitchin, 2000) can be used to map virtual worlds as well as user actions enabling us to guide visitors of VWs and to research the development and usage of 3-D virtual worlds, as well as the evolution of their communities.

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[1] We see a digital city as a special kind of virtual world or virtual environment and will use the terms interchangeably throughout the paper.

While the majority of today's information visualizations are designed for single users, we propose to create 3-D information visualizations that can be collaboratively explored by groups of people to discover important patterns and information hidden in data or to better find, filter, and manage data.

These collaborative information visualizations (CIVs) can be constructed using commercially available 3-D *Online Browser Systems.* Frequently used systems are Blaxxun's online community client-server architecture, Microsoft's Virtual Worlds Platform, Active Worlds technology by Activeworlds Inc., or the new Adobe Atmosphere browser, to name just a few. (URL's are in the references list)

Each of the 3-D browser systems facilitates the creation of multi-modal, multi-user, navigable, and collaborative virtual worlds in 3-D that are interconnected with standard web pages, and that are accessible from standard computer platforms via the Internet, 24 hours and 7 days a week. Damer (1997) provides an excellent review of different systems and existing virtual communities. To appreciate the potential of 3-D browser systems one has to try them out for oneself.

Collaborative 3-D VWs differ from single user systems in that they equip their users with sophisticated self-representations called avatars that wave, dance, and share space. Avatars provide a means of interacting with objects in the VW, embedded information sources and services, or other users. In all these systems, users can communicate synchronously via a chat facility. In addition, VWs facilitate natural, multi-perceptual interaction using spatial sound, animation, and video.

The selection of an appropriate browser system is critical since the technology that mediates user interaction has a great impact on the forms that interaction will take (Jakobsson, 1999; Preece, 2000). Active Worlds (AW) is one of the most popular VW systems. It hosts over six hundred different worlds in the main, entertainment-oriented universe, and more than one hundred worlds in EduVerse, a special universe with an educational focus. AW is based on Render Ware, an interactive 3-D Graphics API. It differs from VRML-based systems in the ease with which participants can build within the world. A user simply selects an existing object, makes a copy of it, and renames it as a different object. Multiple users can work and design artifacts together in a 3-D space without stopping or leaving the world.

Fig. 1 (left panel) shows the AW interface. In contains three main windows: a 3-D graphics panel populated by avatars, a web browser window, and a chat window. At the top are a menu bar and a toolbar for avatar actions. Users can collaboratively navigate in 3-D, move their mouse pointer over an object to bring up its description (see Fig. 2 and 3), click on 3-D objects to display the corresponding web page in the right window of the AW browser, or teleport to more fruitful information patches. The web browser maintains a history of visited places and web pages so that the user can return to previous locations.

Fig. 1 (right panel) shows a sample overview map with area labels of a 3-D virtual world named *iUni* which hosts different learning environments (Börner, 2001a). The map was rendered in 2-D, based on the list of objects that made up the world on Dec 6th, 2000.

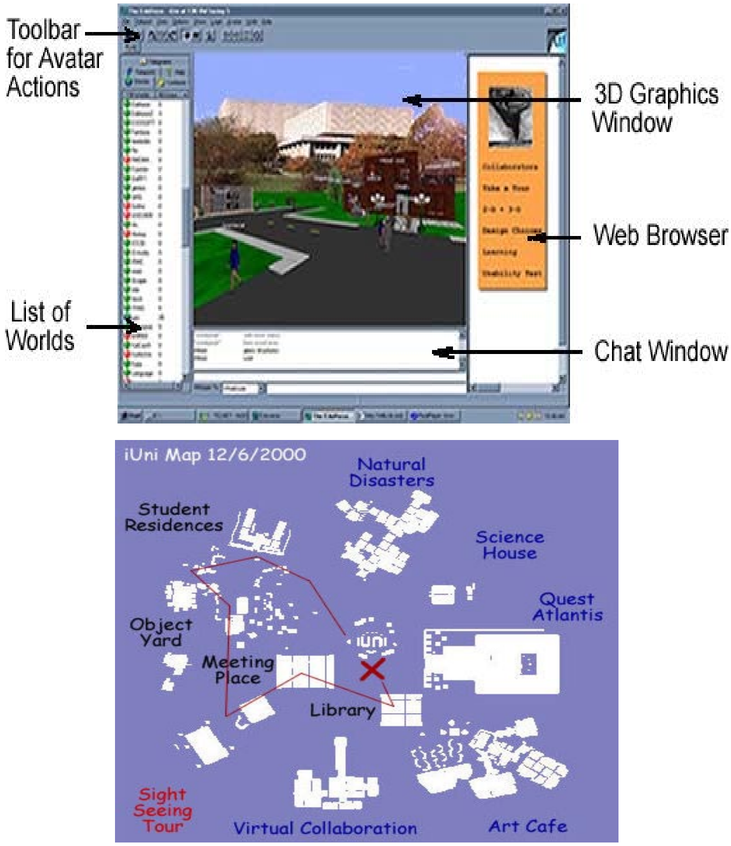

Fig. 1. 3-D AW interface and a 2-D map of a VW

Collaborative information visualizations utilize the 3-D space to connect information to places. In addition, the 3-D space acts as a shared meeting place. The 2-D overview map supports searching and filtering of information and eases navigation. It can be customized to match specific user needs and interests.

Twin Worlds are pairs of CIVs in which one world is used to visualize user interaction data collected in the other world. Subsequently, we exemplify CIVs in terms of a collaborative *Memory Palace* and *Mirror Garden*.

3 Collaborative Memory Palaces

The exponential growth of digital documents makes it increasingly difficult for users to locate relevant resources. Focused digital libraries and repositories help their user communities to contribute and share documents, but necessitate new interfaces for the collaborative contribution, exploration, modification, and management of information. Today, search engines are users' first choice for retrieving documents. However, search engines provide no way to examine the volume and composition of a certain data set or to find out who else is currently interested in the same topic, document, or question. Web search is a very lonely activity. Your friend could query your favorite search engine with the exact term at the very same moment and you both are starring at the endless list of matching documents. However, you have no way to connect or communicate.

Visual interfaces to digital libraries (DLs) aim to visualize the structure of documents or the composition of a database. In addition, they facilitate interactive browsing of large document sets (Börner & Chen, 2001). Typically, they are designed for a single user.

CIVs can be applied to create interfaces to digital libraries and repositories that are highly interactive, visual, and collaborative. The resulting virtual 2-D/3-D places can be seen as abstract digital cities of knowledge tailored for scholars belonging to a certain department, research field, etc.. City districts resemble topic areas and the city map conveys the general composition of a research field.

Like real world libraries, 3-D visual interfaces to DLs provide not only access to information, but also serve as informal meeting places for people with common interests, and are instrumental in the formation of special interest groups.

The concept of 3-D visualizations of documents is not new. Pioneering work by Steve Benford aimed at the organization of document collections either according to hand selected desired mappings or semantic "closeness" based on statistical methods or explicit relations and links between documents. The implemented system, VR-VIBE, enables users to interact with 3-D visualizations of bibliographies. Users can specify keywords that they wish to use and place them in 3-D space. Representations of retrieved documents are then displayed in the 3-D space according to how relevant a document is to each of the specified keywords.

The *Data Mountain* system by (Robertson et al., 1998) exploits spatial memory for document management. It arranges small screen grabs of documents, called thumbnails, on an incline plane textured with passive landmarks. Simple 3-D depth cues such as perspective views and occlusion are used to ease access and management of a large number of web page thumbnails. User studies report reduced storage and retrieval time as well as higher task accuracy for this interface. Similar studies and results for interfaces that exploit spatial memory for information access are reported in (Czerwinski et al., 1999; Woodruff et al., 2001; Cockburn and McKenzie, 2001). However, all these systems are designed for a single user.

The *Knowledge Garden* (Crossley et al., 1999) is one of the very first collaborative information visualizations. It uses VRML to provide a 3-D environment where people can meet colleagues and share relevant information among a community of interest. Agents provide access to shared information resources and facilitate the generation of group or personalized searches and customized knowledge representations. To our knowledge, users can’t contribute new documents to this space and there is no 3-D to 2-D web space connection.

Robertson (2000) describes a web-based digital library that places knowledge sharing and community building at the core of its design. The system supports personal web sites, personal topic profiles for library research services, information service choices, and collaborative research requests that provide people with views of each others' activities and interests and support the formation of special interest groups. He identified four factors essential for community building: place, the ability to see what others are doing, communication and interaction facilities, and individuals acting as facilitators. We fully agree and are interested to design digital cities for scholarly communities that are highly usable, sociable, and pleasurable.

We started to create a collaborative *Memory Palace* for a specific interest group, e.g., students, faculty, and staff in a certain university department (Börner, 2001b). The term *Memory Palace* refers to highly evolved mnemonic structures developed in classical Greek culture to manage and recite great quantities of information. Basically, a *Memory Palace* resembles a non-linear storage system or random access memory that is responsive to the user's position in an imagined space. The more elaborate the palaces, the more information that can be stored, and the more paths lead to the same kind of information.

Anders (1998, p. 34) argues that *"The memory palace could resurface as a model for future collective memory allowing users to navigate stored information in an intuitive spatial manner"* and that *"… cyberspace will evolve to be an important extension of our mental processes"* allowing us to "… *create interactive mnemonic structures to be shared and passed from one generation to the next."* The proposed *Memory Palaces* could serve as an ever-evolving repository of a user community's knowledge that members can discuss, learn from, contribute to, and collectively build upon. Section 5 provides a sample scenario that describes what users experience in this space as well as basic technical details.

4 Mirror Gardens

A large number of diverse social visualizations have been developed to show data about a person, illuminate relationships among people, or to visualize user group activity. Börner & Lin (2001) provide an extensive review of existing approaches and systems.[2]

Owners of virtual worlds or digital cities are most likely interested in answers to questions such as: "Who is using it?", "What do people do?", "What resources do they access?" among many others (van den Besselaar et al, 2000). At the same time, there is a need for more sophisticated navigation support for users as well as awareness tools[3] to find out "What places to see, what to do?", "What are the most popular

[2] Not covered in this review is the eRENA project (http://www.nada.kth.se/erena/) which developed tools for 3-D recording and playback that can be utilized in post-production or for the creation of new kinds of animation and virtual experiences.

[3] TOWER is the name of a recent project (http://orgwis.gmd.de/projects/tower/) that aims to support cooperation and awareness in co-located teams (Prinz et al., 2000). It augments existing systems through sensors which detect user operations in the respective systems and discloses them in a 3-D *Theatre of Work* world.

places/documents?", "What is new?", "Who is online?", "Whom can I ask for which information?", "When is xx typically available and where?", etc.

To answer these questions, we suggest collecting user interaction data such as navigation, manipulation, chatting, and web access activity, and visualizing these data sets in a second twin world which we call *Mirror Garden*. The term *Mirror Garden* was derived by merging the term *Mirror World* as envisioned by Gelernter (1992) and *PeopleGarden* coined by Xiong & Donath (1999).[4]

The *Mirror Garden* world utilizes a 2-D overview map and a 3-D CIV space to visualize usage patterns of interest such as:

- **General usage patterns:** Where do users login from? Who are they? How long do they stay? Do they login regularly or irregularly? How many people are in the world at which time? Are there general bursts of activity?
- **Navigation patterns:** Which general routes do users take? What are the most popular places? How do people move and place themselves in urban space? Are there well-traveled paths that may indicate a particular problem solving strategy? Which places are multi-way branching places, pass through places, or (final) destination areas?
- **Manipulation patterns:** Who manipulates (creates, modifies, deletes) which objects, and when?
- **Conversation patterns:** Where do people talk? Which places in 3-D are used for long, intricate discussions, and which are sites of quick exchanges? How long, what about, and to whom do people talk? What is the size of conversational groups? How do conversational topics evolve? How does the environment influence conversational topics?
- **Web access patterns:** Which web pages are accessed by whom, when, from where, and how often?

In this way, the *Mirror Garden* provides navigation support for visitors of virtual worlds and helps designers with the organization and layout of world content and the tuning of interaction possibilities. In addition, it can serve as a research tool to study virtual worlds and their evolving communities.

5 Twin Worlds in Action – The SLIS Document Space

To demonstrate the twin world approach we began to implement two worlds – iPalace and iGarden – in Active World's Educational Universe.

The iPalace – *Memory Palace* – world aims to support collaborative information access and management. It consists of semantically organized online documents laid

[4] Xiong & Donath's (1999) system uses a particularly apt flower metaphor to create individual data portraits of chat participants and a garden metaphor for combining these portraits to present a visualization of conversation activity.

out in a 3-D space. About 530 people – including about 300 students in Bloomington and 200 students in Indianapolis - will have access to this space.

It is seeded with about 8,000 links to online documents such as text, images, video, software demonstrations, etc. collected from personal favorites or bookmark lists created by SLIS faculty. The full text of all documents was retrieved and semantically analyzed using data mining techniques such as *Latent Semantic Analysis* (Landauer et al., 1998). The resulting document-by-document similarity matrix was used to group semantically similar documents. The explanation of these techniques would go beyond the scope of this paper. The reader may consult the author's work on the *LVis – Digital Library Visualizer* project (Börner, 2000a; Börner, 2000b; Börner et al., 2000) for details.

Subsequently, data layout algorithms such as Treemaps (Shneiderman, 1992) were used to spatially organize topic areas – each representing a set of semantically similar documents – in 2-D space. The resulting 2-D layout is used to position web page links in the 3-D iPalace world. In 3-D, each document is represented by a square panel textured by the corresponding web page's thumbnail image and augmented by a short description such as the web page title (similar to Robertson et al's, [1998] *Data Mountain* interface). The objects that make up the 3-D world are rendered in a Java applet as a 2-D topic map that is displayed in the web interface for navigation purposes. Users are able to click on the map in order to teleport into the corresponding topic area in the 3-D space. Users can enter particular search terms, which results in highlighted web pages containing those terms in the 2-D map. This way, areas containing documents of interest can be easily identified. In addition, users can collaboratively examine, discuss, and modify (add/delete resources, annotate) documents, thereby converting this document space into an ever-evolving repository of the user community's collective knowledge that members can access, learn from, contribute to, and build upon. The space becomes a shared *Memory Palace* representing the knowledge of the community.

The iGarden – *Mirror Garden* – world visualizes user interaction data such as navigation, manipulation, chatting, and web access activity (Börner & Lin, 2001) utilizing a 3-D world and corresponding 2-D map. It is created based on mined logs that have been collected in the *Memory Palace*. It can be used to guide users, to evaluate the effectiveness and usability of the world and to optimize design properties, or to examine the evolving user community. The explanation of the user interaction data analysis and visualization techniques are beyond the scope of this paper.

Below are two scenarios that aim to convey the appearance and functionality of both worlds.

Scenario#1 – The iPalace world: Imagine you are a student who is taking the Human-Computer Interaction course and you are interested in documents on usability. You launch the 3-D online browser and login to the iPalace world using your self-selected virtual nickname and avatar.

Your avatar is placed in the middle of a square world; the sky is filled with photos of influential people in the fields of Human Computer Interaction, Usability Studies, Human Factors, Interface Design, etc. guiding your navigation. In front of you are different teleports. You click on the one that says “Usability Studies” and your avatar is instantly teleported to an area filled with 3-D objects that link to documents on this topic. The objects are textured with thumbnail images of corresponding documents. You quickly recognize some new objects. Objects at higher elevations link to documents that other users found particularly relevant. Moving the mouse pointer over an object brings up a short description of the document and its number. Clicking on objects brings up the corresponding document in the 2-D web interface for reading, printing, etc. (see Fig. 2). Alternatively, you can enter a search term “Usability” in the 2-D web interface which highlights relevant documents on the 2-D map. Clicking on a document displayed in the 2-D map instantly teleports you to the corresponding 3-D space so that similar references can be explored. You might also see other users in this space whom you can ask for relevant documents and advice. Lonely web searching and browsing can thus be converted into a collaborative examination and discussion of documents.

In addition, you can modify this world. For example, you can change the relevance of a document by communicating with a helpful bot (machine program) named HelpMe. The corresponding chat messages would read “HelpMe document#:=relevance#.” The relevance value can be set between 0 and 99 and its average number will be reflected by the height of the document's object. Alternatively, you can add documents via the web interface. The new documents will be accessible in the 3-D world after the next update.

You may also want to find users that are interested in similar topics. You teleport into the iGarden world (see scenario #2) to find chat or document access activity that matches certain topics.

Fig. 2. Still of the iPalace – *Memory Palace* – world

Scenario #2 – The iGarden world: Imagine you are part of the iPalace Wizard group and interested in examining the usage patterns of the world. You enter the iGarden - a magic world of glass and flowers (see Fig. 3). All objects you remember from the iPalace world are replaced by transparent objects of similar shapes. Some of these objects carry abstract symbols to indicate that they link to web pages, function as teleports, activate sound sources, etc. Another set of abstract symbols, e.g., flowers, is used to visualize user interaction data.

You are especially interested in web access patterns during the last two months. Utilizing the 2-D map, you filter out user activity in this time span and quickly identify the most often accessed web links. Also, you are curious to see if the new design of the entrance area improves communication. You click on the corresponding 2-D map to teleport into the 3-D entrance area. Happily, you see that there are many new flower patches in this area indicating that many discussions have taken place. Additionally, you would like to know if the latest teleport to the meeting area was used. At this point, you consult the 2-D map again and notice that so far it has only been used twice. In order to find out where people talk about usability issues, you enter the term into the “search for semantically similar chat text” window and the 2-D map shows dots at all the places in which users discussed usability. At any time, you can hit a button on the 2-D web interface, and you will be transported into the corresponding place in the iPalace world.

Fig. 3. Still of the iGarden – *Mirror Garden* – world

Note that both worlds are automatically (re)created in fixed cycles to ensure incorporation of new documents into the iPalace world and an up-to-date status of the iGarden. Both worlds are adaptive, collaborative information visualizations that provide access to either online documents or user interaction data. Both support all three major navigation paradigms (Dourish and Chalmers, 1994): spatial navigation – mimicking our experiences in the physical world; semantic navigation – driven by semantic relationships or underlying logic; and social navigation – taking advantage of the behavior of like-minded people.

User participation and collaboration is encouraged by organization of regular events such as reading groups that discuss influential documents, specific research topics, etc.

Please feel free to visit our virtual worlds via http://vw.indiana.edu/.

6 Discussion

Computers are evolving from a mathematical engine, a data/information engine in administrative systems, a personalized tool to support the competence of a skilled worker, and an autonomous agent capable of learning, helping and giving advice, into a *mediator of human-to-human interaction* (Holmström & Jakobsson, 2001, p.1). Similarly, the real transformative power of the Internet seems to come from the new and varied forms of communication that it enables among people (Dodge, 2001). The high interest in collaborative digital cities and virtual worlds reflects this trend.

However, the design and evaluation of collaborative spaces and the steering and nourishment of their evolving communities requires new approaches and techniques to monitor and optimize them.

This paper proposed collaborative information visualizations and the utilization of twin worlds to:

- Assist users in making sense of the world and its information resources as well as to increase awareness of collaboration possibilities.
- Aid designers of user-centered 3-D VWs in the evaluation and optimization of world content and layout as well as the selection of interaction possibilities
- Enable researchers to monitor, study, and research VWs and their evolving communities.

We believe that CIVs and the approach of twin worlds can help to match a DC to the interests and interactions of its inhabitants and to avoid its degeneration into a public database, a glossy brochure promoting a real town, an elaborate 3-D model, or a communication facility that fails to promote and nourish a community.

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Digital City Kyoto http://www.digitalcity.gr.jp
Virtual Los Angeles http://www.aud.ucla.edu/~bill/ACM97.html
Virtual Bremen http://www.vc.org/deutschland/bremen/bremen/
Digital City Amsterdam http://www.dds.nl

Blaxxun's online community client-server architecture http://www.blaxxun.com/community
Microsoft's Virtual Worlds Platform http://www.vworlds.org/
Active Worlds technology http://www.activeworlds.com/
Adobe Atmosphere browser http://www.adobe.com/products/atmosphere/
VIBE http://www.crg.cs.nott.ac.uk/research/technologies/visualisation/vrvibe/