Title	2LIP: Filling the Gap between the Current and the Three-Dimensional Web
Author(s)	Jankowski, Jacek; Decker, Stefan
Publication Date	2009
Publication Information	Jacek Jankowski, Stefan Decker "2LIP: Filling the Gap between the Current and the Three-Dimensional Web", Proceedings of the 14th International Conference on 3D Web Technology 2009, 2009.
Item record	http://hdl.handle.net/10379/1090

2LIP: Filling The Gap Between The Current And The Three-Dimensional Web

Jacek Jankowski, Stefan Decker*
Digital Enterprise Research Institute
National University of Ireland, Galway, Ireland

Abstract

In this article we present a novel approach, the 2-Layer Interface Paradigm (2LIP), for designing simple yet interactive 3D web applications, an attempt to marry advantages of 3D experience with the advantages of the narrative structure of hypertext. The hypertext information, together with graphics, and multimedia, is presented semi-transparently on the foreground layer. It overlays the 3D representation of the information displayed in the background of the interface. Hyperlinks are used for navigation in the 3D scenes (in both layers).

We introduce a reference implementation of 2LIP: Copernicus - The Virtual 3D Encyclopedia, which can become a model for building 3D Wikipedia. Based on the evaluation of Copernicus we show that designing web interfaces according to 2LIP provides users with a better experience during browsing the Web, has a positive effect on the visual and associative memory, improves spatial cognition of presented information, and increases overall user's satisfaction without harming the interaction.

CR Categories: H.5.2 [Information Interfaces and Presentation]: User Interfaces—Graphical User Interfaces (GUI), Interaction Styles, Evaluation/Methodology; H.5.4 [Information Interfaces and Presentation]: Hypertext and Hypermedia—User Issues;

Keywords: Design, 2LIP, Copernicus, 3D Hypermedia, 3D Web, Transparency, Wiki

1 Introduction

The Web is a collection of documents and other resources linked by hyperlinks. It changes and evolves, but its definition is still the same after twenty years of existence. Its interface and structure are consistently determined by the concept of the hyperlink, a directed relationship between two objects, and as the Web evolves towards a network of social interaction, Semantic Web [Berners-Lee et al. 2001], and 3D Web [Forrester 2008], we believe that hyperlinks will remain the primary navigational means of the WWW.

Online Virtual Realities provide us with an opportunity to have experiences that would otherwise be impossible. We can interact and learn in three-dimensional environments that represent present or past cultural heritage monuments, museums along with its exhibits, or other interesting places that would be inaccessible or even not possible to visit for an average Internet user. Thanks to the fast increase in the performance of affordable graphics hardware, we can explore virtual worlds, which are competitive with our real world. However, 3D navigation techniques, even simple ones, can be very difficult to learn, resulting in many users giving up 3D interaction,

which might be hard to understand in the context of the Internet hypertext environment.

We strongly believe that user interfaces should be as simple as possible. We have worked out a new way for designing interactive 3D web applications - 2-Layer Interface Paradigm (2LIP) [Jankowski and Kruk 2008]. 2LIP is an attempt to marry advantages of 3D experience with the advantages of the narrative structure of hypertext. It assumes that building graphical user interfaces involves the integration of two layers (see Figure 1): (1) the background layer is a 3D scene; (2) the foreground layer, above the 3D view is the hypertextual content, together with graphics, and multimedia (e.g., videos or other interactive 3D scenes). Hyperlinks are used for navigation in the 3D scenes (in both layers).

Figure 1: *The idea behind 2LIP.*

The key research problem addressed in this paper is to design simple yet interactive 3D hypermedia interface that better supports human attention, has a positive effect on the visual memory, improves spatial cognition of presented information, and increases overall user's satisfaction. We hope that our solution can take what is best from the third dimension and, without harming the interaction, provide users a better experience during browsing the Web than the contemporary 2D-based, hypertext interfaces.

2 Related Work

2.1 Hypertext/Hypermedia

Hypertext and Hypermedia are usually seen as originating in Vannevar Bush's historical article "As We May Think" from 1945 [Bush 1945] and in the concept of nonlinear texts proposed by Ted Nelson in 1974 [Nelson 1974]. According to their visions, hypertext enables a dynamic organization of information through links and connections (called hyperlinks). Hypermedia is used as a logical extension of the term hypertext in which graphics, audio, video, or animations can be presented as a non-linear medium of information.

2.1.1 3D Hypermedia

In 1992, during the Conference on Hypertext and Hypermedia, Jay D. Bolter gave a keynote speech on Virtual Reality and the Future of Hypertext [Bolter 1992], where he described how the two can be combined:

---

*e-mail: firstname.lastname@deri.org

"What role might text play in Virtual Reality (VR)? One could convincingly argue there is no real direct competition. VR is useful for simulation and training. Hypertext serves for text materials. Can the two be combined? In particular, can the space of virtual reality be hypertextualized?
One way to introduce text into virtual reality would be to write upon the surfaces in the virtual space. (...) A more radical possibility would be to turn the entire virtual space into a symbolic structure. Such a hypertextualized virtual space might allow the creation of text unlike any that have ever been written."

This vision inspired researchers from Graz University of Technology. Andrews and Pichler in [Andrews and Pichler 1994] examine the incorporation of three-dimensional models into hypermedia systems as fully-fledged documents. Display, navigational, and authoring aspects of 3D hypermedia documents are discussed and are illustrated with examples taken from the Harmony Viewer for the Hyper-G hypermedia information system [Andrews 1994].

2.1.2 World Wide Web

Hyperlinks are the primary navigational means of the Web, currently the most popular Internet hypertext system. Recent studies have shown that following links is still the most frequent action when using a Web browser: Weinreich et al. reported 46% of user actions are clicks on links [Weinreich et al. 2008].

2.1.3 3D Hypermedia on the Web

Virtual Reality Markup Language (VRML), designed for creating 3D interactive graphics on the Web, reached the summit of its popularity after the second edition release in 1997, when it was used to build some personal homepages and sites. X3D, developed by the Web3D Consortium, is the successor to VRML. It supports two approaches for interaction with external environments, namely SAI (Scene Authoring Interface) and older, defined by the VRML standard, EAI (External Authoring Interface). SAI forms a common interface that can be used for manipulating the scene graph from either an external application or from inside the scene graph. For example, it can be employed to control/manipulate embedded in HTML VRML/X3D scenes via JavaScript.

2.2 Guided/Constrained 3D Navigation

3D navigation techniques, even simple ones, can be very difficult to learn, resulting in many users giving up 3D interaction. Guided/Constrained 3D navigation limits the user's freedom while travelling through a virtual world. It constrains the audience's movement to interesting and compelling places, and thus avoids the classic problem of users getting 'lost-in-cyberspace'. It was introduced by Galyean, who proposed "The River Analogy" [Galyean 1995], where the user is a boat floating down this river with some control. Burtnyk et al. describe StyleCam [Burtnyk et al. 2002], an approach for authoring 3D viewing experiences that seamlessly integrates spatial camera control with the temporal control of animation playback. Safe 3D Navigation reduces the occurrence of confusing situations [Fitzmaurice et al. 2008].

For the 3D Web context, Chittaro et al. in [Chittaro et al. 2003] propose the adoption of guided tours of virtual worlds as an effective user aid and describe a tool that provides automatic code generation for adding such guided tours to VRML worlds. Magallanes [Abasolo and Della 2007] can be added to any new or existent VRML scene to generate a graphical user interface that facilitates the selection of places of interest.

2.3 2D versus 3D

Some designers aim at building interfaces that approach the richness of three-dimensional reality. They believe that the closer the interfaces are to the real world, the easier usage will be. Nevertheless, user studies proved that complex and disorienting navigation and annoying occlusions can slow performance in 3D interfaces [Cockburn and McKenzie 2002; Risden et al. 2000; Sutcliffe and Patel 1996]. In other words: the 3D world can give an extra degree of freedom, but sometimes the extra degree of freedom also leads to confusions and complications [Chen 2004].

Certainly the performance is not always the most important factor for designers. The positive effect of adding another dimension to the interface on spatial cognition (the acquisition, organization, utilization, and revision of knowledge about spatial environments), associative memory (ability to recall one part of relationship when seeing the other part), and visual memory (ability to remember configuration, location, orientation of figural material) is proved as well [Chen 2004].

2.4 Transparency

Transparency has been proposed and implemented as an answer to the problem of occlusion and limited screen space. It has been adopted into some operating systems (e.g., MacOS X and Linux, where semi-transparent terminals are favored by many users) and many games (e.g., World of Warcraft - to show maps). However, it still seems to be far from reaching its potential.

Several research works have already addressed the subject of transparency. Alpha blending has been explored and evaluated by Harrison and colleagues [Harrison et al. 1995], who found that it can improve workspace visibility without harming interaction performance. Multiblending [Baudisch and Gutwin 2004] uses a vector of blending weights rather than a single transparency value to preserve the most relevant features of overlapping windows in visual workspaces. Ishak and Fainer work on content-aware free-space transparency (FST) allowing a user to make efficient use of screen space by rendering unimportant window regions transparent and important window regions opaque, with a smooth gradient between them [Ishak and Feiner 2004]. In every case transparency offered a more seamless interaction.

2.5 Focus + Context

The Focus + Context (F+C) information visualization technique allows users to have the information of interest in the foreground and all the remaining information in the background simultaneously visible [Card and Mackinlay 1999; Furnas 1986]. For example, in [Shiaw et al. 2004], Shiaw et al. present an approach to displaying and browsing a digital library collection, a set of Greek vases in the Perseus digital library, which takes advantage of 3D graphics to preserve context.

Our approach to information visualization on the Web also draws on the F+C technique. 2LIP links textual, 3D and video based information presented on the foreground (focus) with an optional spatial overview displayed in the background of the interface (context).

2.6 Integration of Text and 3D Presentation

There is a small but growing body of research related to integration of text with visual representation. Bell et al. describe a view-management component for interactive 3D user interfaces that support dynamic labeling [Bell et al. 2001]. Ritter and colleagues use shadow of 3D objects for both emphasizing scene objects and as
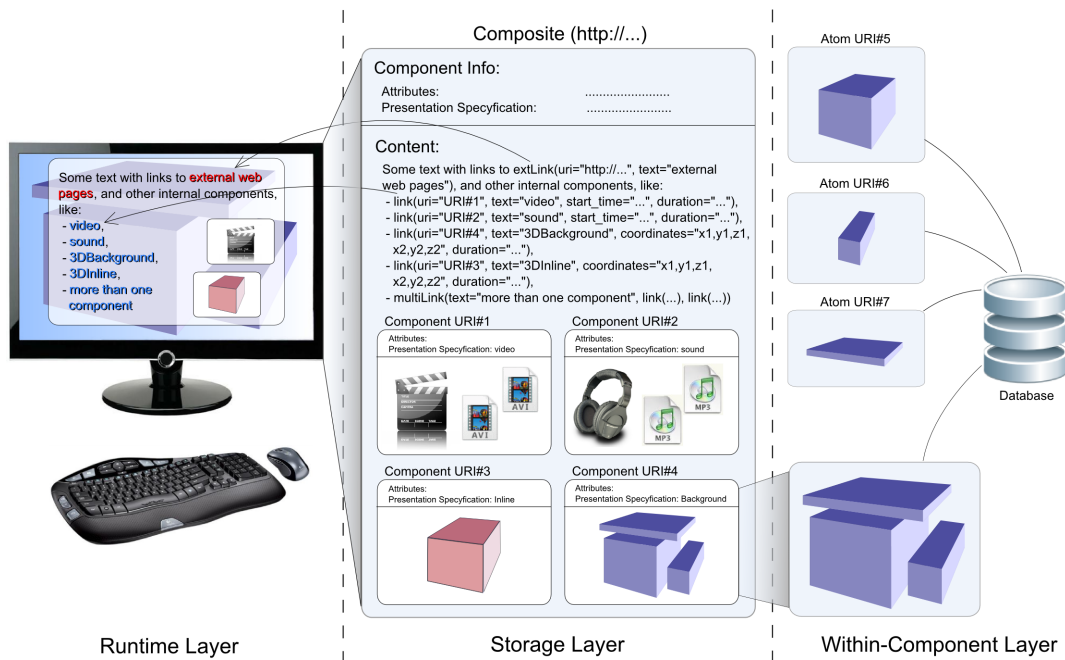
Figure 2: *A depiction of the three layers of the 2LIP model (based on Dexter model).*

reference for annotations [Chigona et al. 2003; Ritter et al. 2003]. In [Jung et al. 2002], Jung et al. describe a system for collaborative work that allows people to leave notes, which can be retrieved in a separate window.

In the very interesting article [Sonnet et al. 2004], Sonnet et al. introduce Expanding Annotations, the methodology to present text information adjacent to associated scene objects. The annotations expand smoothly on demand and are rendered as 2D semi-transparent polygons in screen space. In all of those cases presentation of text is considered as an additional option during interaction in virtual environments, whereas in 2LIP a 3D representation is the completion of hypertext.

2.7 Animation and Learning

Animation is usually used to provide a continuous transition from one state of the interface to another, and has become increasingly common, both in research and commercial user interfaces. It helps users maintain object constancy - it was well described in [Robertson et al. 1991]:

"Interactive animation is used to shift some of the user's cognitive load to the human perceptual system. (...) The perceptual phenomenon of object constancy enables the user to track substructure relationships without thinking about it. When the animation is completed, no time is needed for reassimilation."

In [Bederson and Boltman 1999], Bederson et al. examine how animating a viewpoint change in a spatial information system affects a user's ability to build a mental map of the information in the space. They found that animation improves users' ability to reconstruct the information space, with no penalty on task performance time.

2.8 Augmented Reality

Augmented realty (AR) is a combination of real world and computer-generated data [Feiner 2002]. Contemporary usage of this technique is focused mainly on processing real-time data and "augmenting" it by the addition of computer generated graphics, e.g., showing virtual lines and commercials in football games' broadcasts. Compared to Virtual Reality, AR allows for presenting a virtual world that enriches, rather then replaces, the real world. Instead of blocking out the real world, this approach annotates reality to provide valuable information, such as description of important features or instructions for performing tasks.

Our idea derives from the AR concept. Instead of creating a layer over the real world, we put the informational hypertext-layer on the top of the computer generated three-dimensional scene.

3 2LIP - A Consensus Solution

The Web is praised for being easy to use. 3D Web was believed to have potential to be the next step in the Web's evolution, since it could benefit from graphics hardware and provide users with new and exciting experiences. Nevertheless, VRML and X3D are still recognizable only among researchers. One of the reasons is difficult interaction model which might be pretty hard to understand in the context of the web environment. Our approach to this problem is to introduce a level of 3D-based entertainment, and couple it with well adapted 2D-based interactions - clicking on hyperlinks.

3.1 The 2LIP Model

The 2LIP model is based on the Amsterdam Hypermedia Model (AHM) [Hardman et al. 1994], which is the descendant of the Dexter Reference Model (DRM) [Halasz and Schwartz 1994]. Figure 3 presents how the elements of our model are placed in the DRM and the AHM.

Figure 2 presents the three layers of the 2LIP model: run-time layer (it is responsible for presentation of the component to the user), storage layer (it models the basic node/link network structure) and within-component layer (it is concerned with the contents and the

DRM/AHM	2LIP Model
Runtime Layer	Data representation in two layers
Presentation Specification	Background: 3D scene, Foreground: hypertext + multimedia (3D, video, ...)
Storage Layer	Composites (metadata + textual content with links to external resources or internal components)
Anchoring	Source anchors: parts in text Destination anchors: for 3D models – coordinates in 3D space, for video and sound – time in recordings.
Within-Component Layer	Resources that can be addressed by URIs

Figure 3: *2LIP and DRM/AHM.*

structure within the components - in our case web resources that can be addressed by URIs).

The main difference between the 2LIP model and the Dexter model is in the storage layer. As in HTML, we do not define a separate link entity. Such an approach has one obvious drawback - users cannot create bi-directional links. However, defining links in text using in-line style became established technique - even novice Internet users can create such links using HTML.

In Figure 2, the Storage Layer contains the pseudo-code needed to render the page in the Runtime Layer. The notation of the links with uri=uri#1 and uri=uri#2 (video and sound respectively) is based on AHM. The coordinates and duration elements in the notation of the links with uri=uri#3 and uri=uri#4 define the position of the camera (x1,y1,z1), the viewpoint (x2,y2,z2), and time of the camera movement. We created the model that can be easily employed to the existing web infrastructure. We aim to facilitate the development of new usages on the Web and lay a foundation for new web hypermedia applications (see [Jankowski et al. 2009] or visit: http://2LIPGarden.deri.ie).

3.2   User Interface

2LIP assumes that building graphical user interfaces involves the integration of two layers (see Figure 2: Runtime Layer):

- the background - a 3D scene;
- the foreground - a 2D information and interaction layer.

The hypertext information, together with graphics, multimedia and interaction interface, is presented semi-transparently on the foreground layer. This is the primary information carrier of the 2LIP model. The key concepts presented by the given web site are presented on this layer. The information presented on this layer should consist of hypertext, images and a number of multimedia elements, such as videos and 3D visualizations. It should not be overwhelmed with large and non-transparent items.

The background layer introduces the additional entertainment and educational aspect to the information presented in the foreground. Information presented on the foreground can be visualized with the 3D representation displayed in the background of the interface.

For navigation in 3D scenes (in both layers) we decided to use the constrained 3D navigation metaphor to facilitate the interaction and to avoid the classic problem of users getting 'lost-in-cyberspace'. It is possible to "browse" the scene following predefined paths (interpolated camera moves) invoked from the interaction interface on

the foreground layer simply by clicking on hyperlinks. For the duration of the background animation the opacity of the front layer is automatically lowered to 0 (fully transparent).

3.3   Expected Improvement

The presented model of 2LIP interface builds upon well established hypertext interactions. We foresee that compared to other attempts to introduce full fledged 3D environment to the Web, 2LIP avoids some problems:

- Users do not have to learn a new interaction model, which might be pretty hard to understand in the context of the web environment;

- It is possible to read without the 3D scene; the information is not scattered or embedded into the 3D scene, but rather presented in a concise form familiar to the Internet users.

We have identified the number of hypotheses related to how the 2LIP model enhances the classic HTML model with the number of positive features:

1. Binding hypertext with 3D scenes has a positive effect on the visual and associative memory. Users are able to remember presented information longer, and with more details.

2. The 2LIP model improves spatial cognition of presented information. Users can actually see the location of objects presented in the hypertext; they can better understand and remember shapes and relative distances of described items.

3. A 3D scene in the background layer, together with simple 2D-based navigation increases overall user's satisfaction. Users are more likely to spend more time reading and interacting with presented information, than when compared to classic 2D model of the hypertext rendering solutions.

Our approach does not drastically change the style of interaction, from the one users were used to in classic HTML pages. It allows the users to adapt gradually, over the time, to the new approach of presenting information. In section 4 we will present results of the evaluation, and analyze them in the context of aforementioned three hypotheses.

3.4   Copernicus - 2LIP in Practice

In order to illustrate and evaluate the 2LIP model we have implemented the prototype system called Copernicus (see http://copernicus.deri.ie). It was designed to resemble Wikipedia. We decided to try to bring this most popular online encyclopedia into the third dimension.
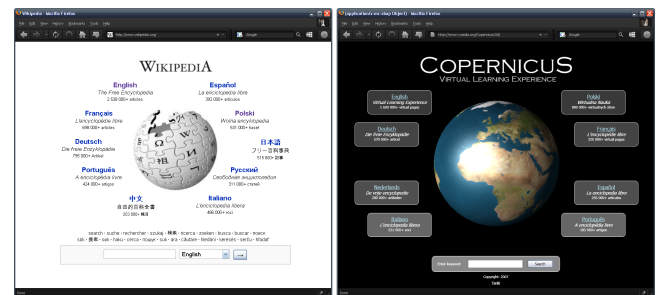

Figure 4: *Welcome pages of Wikipedia and Copernicus.*

3.4.1 Entering Copernicus

From the graphical point of view, the welcome page of Copernicus is very similar to the home page of Wikipedia (see Figure 4). The major difference the user can notice is an animation of a spinning Earth instead of a sphere of puzzles.

Once the user had performed the search and chose one of the results, related to information about a specific geographical region, the camera will move to this particular place on the spinning globe. For instance: the camera will "fly" towards the Central Europe as a result of searching for "polish heritage park"; eventually, the Polish Heritage Park in Olsztyn will be presented to the user (see Figure 5). This place, actually, does not exist in the real world - the scene was created only for evaluation purposes.
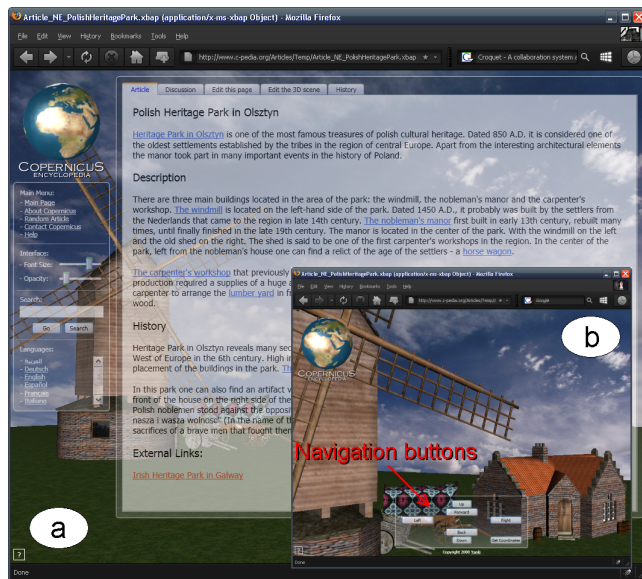
Figure 5: *(a) The article. (b) The free navigation mode.*

3.4.2 Wiki Pages with 3D scenes

Pages with articles are also similar to those from Wikipedia. Their layout is generally the same; the menu on the left hand side, the article on the right hand side. The menu part provides additional options: users can change the font size and the transparency of the presented text using a set of sliders; they can make their reading experience more convenient by adjusting these parameters. In addition to a classic wiki page, the background is a three dimensional visualization of the place/object described in the article (see Figure 5).

While reading an article, the user can be presented with details from the 3D scene; clicking on the blue hyperlinks (there are two kinds of links in the articles: the blue links (c-links) to the places on the 3D scene and the red links to the other, external web resources), e.g., related to interesting places, or scrolling the text of the article, triggers a predefined camera movement. For example: a user reading an article about Polish Heritage Park in Olsztyn (see Figure 5a) might be interested in taking a closer look at a flag used during the great rebellion. Clicking the "flag" link triggers the animation. The camera will smoothly move over the 3D scene following the predefined motion path; it will stop behind the workshop showing this historical artifact. For the duration of the animation the opacity of the front layer is automatically lowered to 0 (fully transparent).

Users can also switch to the free navigation mode (see Figure 5b) at any time - it supports 3D interactions such as zoom, rotate, etc.

3.4.3 Authoring Wiki Pages

As Wikipedia became successful because it was written collaboratively, we are also going to give potential users an opportunity for collaboration. We work on a content editor (see Figure 6), conceptually similar to the one from MediaWiki. The process of creating new Copernicus page consist of writing an article using a wiki markup language and composing a 3D scene from objects used on other scenes (option for wikimaniacs) or uploading a 3D models or scenes (option for 3D geeks).
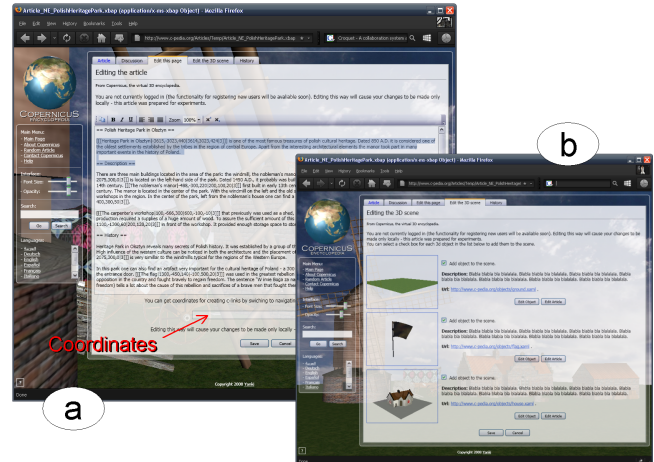
Figure 6: *Authoring: (a) the text and (b) the 3D edit tab.*

Once the author has created the 3D scene and has written the article, the interesting places in the 3D scene may be selected and connected to the links in the text. To create such c-link the author has to switch to the free navigation mode, position the camera, and click the "get coordinates" button (similarly to adding viewpoints in Magallanes [Abasolo and Della 2007]). After that, the system will automatically switch back to the edit mode with the coordinates in the textbox (see Figure 5a); the author can use them to create the c-link:

$$[[[c - link\ name | x1, y1, z1 | x2, y2, z2 | t]]]$$

where: (x1,y1,z1) - the position of camera, (x2,y2,z2) - the viewpoint, t - time of the camera movement. This notion is very similar to the notion of a link in the wiki markup; therefore, we hope that wikimaniacs and other creative internet users will have no problem with using our system.

3.4.4 Implementation

The beginning of the work on Copernicus was coeval with launching of the version 3.0 of .Net Framework. One of the components of this framework is the Windows Presentation Foundation (WPF); it uses Extensible Application Markup Language (XAML) as the user interface markup language. XAML allows defining UI elements, 2D and 3D objects, animations, data binding, and events. It is also the one of the first technologies that can take advantage of the GPU. XAML features allow to easily deliver solutions that can combine 2D and 3D objects; in our case 3D scene and structured text. We have decided to use XAML to prototype our first 3D Web solution. The only shortcoming of using XAML is that the web pages can only be rendered using Internet Explorer (it needs

.Net Framework 3.0) or Firefox (it needs .Net Framework 3.5) on Windows. We hope, however, that either XAML will be adapted by other web browsers, or other similar solutions will be delivered, or both.

3.5 Other Possible Applications of 2LIP

3.5.1 2LIPGarden - 3D Hypermedia for Everyone

2LIPGarden is a 3D Hypermedia publishing framework designed to significantly lower the barrier for authoring 3D websites ([Jankowski et al. 2009] or visit: http://2LIPGarden.deri.ie). It enables people using predefined 3D backgrounds. Instead of writing the line:

$$< body\ background = "/images/image\ name.jpg" >$$

they can simply choose a 3D scene from the list and add it to their web pages as the second layer. One of the examples of such a predefined scene can be an idyllic view on nature.

3.5.2 Online Advertising

Online advertising is currently one of the biggest markets worldwide. The Yankee Group predicts that just in the U.S. it will generate annual revenue of $50.3 billion by 2011, more than doubling 2007's revenue. However, many of the solutions used in online advertising, such as: pop-ups, floating ads, trick banners are not welcome by the majority of Internet users. 2LIP can improve this situation. Thanks to our paradigm, advertisements can be added to websites in the traditional way, but they can also be placed in the background of 3D pages. Users will be able to perform actions and see commercials at the same time.

There is also another way of advertising in 2LIP-type websites, less visible for end-users. Advertisements can be placed on objects of the 3D scenes. For example: a logo of a company that produces swords can be placed on the wall of the blacksmith/workshop that is included in the 3D scene in the article about Polish Heritage Park in Olsztyn.

Both proposed solutions of advertising using 2-LIP are less aggressive than pop-ups or trick banners, hence they are less inconvenient for the users. Nonetheless, these advertisements remain noticeable and draw users' attention. Moreover, the implementation of such kind of advertising is not difficult - in the simplest scenario logos and banners can be incorporated to the textures used in the scene.

4 Evaluation

In this section we will describe the evaluation setup. First we discuss the questions for the evaluation. This discussion is followed by the description of the experiment setup where we describe the method used in the experiment. Finally we present and discuss the results of the experiment.

4.1 Questions for the Evaluation

In the section 3.3 we have discussed hypotheses related to how 2LIP model enhances classic 2D model. Based on these hypotheses we defined a number of questions that our experiment is designed to answer.

Question 1 - Does binding hypertext with a 3D scene have a positive effect on the visual and associative memory? We would like to determine whether users tend to remember more visual aspects (such as placement of the objects) of the described scene when using Copernicus.

Question 2 - Does the 2LIP model improve spatial cognition of presented information? We would like to determine whether because of the fact that the users can actually see the location of objects presented in the hypertext they can better understand and remember shapes and relative distances of described items.

Question 3 - Does an animated 3D scene in the background layer, together with simple 2D-based navigation increase overall user's satisfaction? We would like to determine whether the users are more likely to spend more time reading and interacting with presented information, than when compared to classic 2D model of the hypertext rendering solutions.

4.2 Experiment setup

In this section we concentrate on the evaluation experiment setup. We present the apparatus - a set of the articles prepared for the purpose of this experiment. We also describe in detail the procedure of the experiment.

4.2.1 Materials

For the purpose of this experiment we prepared 4 articles (see http://copernicus.deri.ie/Description.aspx, the Evaluation section). Two shorter articles were describing existing locations (complex of pyramids in Giza and Maya Chichen Itza pyramid). These articles were less complex and presented only the general information about the localizations. To prevent the influence of previously gathered knowledge we decided to prepare two other articles which described non-existing localizations. The latter articles were more complex and gave a lot more information than the first two. All the articles were accessible in the same form both with Copernicus and the MediaWiki system (see Figure 7). Each article presented information about a given localization:
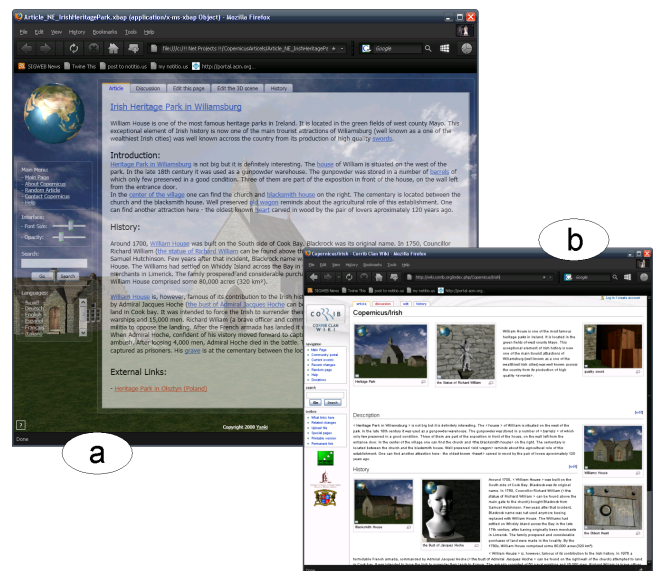
Figure 7: *The articles about Irish Heritage Park in both (a) Copernicus prototype and (b) MediaWiki.*

Chichen Itza - the article contains historical and geographical information about the Maya Chichen Itza complex. The article consisted of about 350 words and 4 images representing the overview and the most important objects in the complex. 3 objects were explicitly identified and described in the article.

Giza - the article presented historical and geographical information about the complex of pyramids in Egypt. The article consisted of about 520 words and 4 images representing the overview and the most important objects in the complex. Two objects were explicitly identified and described in the article.

Polish Heritage Park - the article gave an overview of a non-existing heritage park in Poland. The article consisted of about 450 words and 5 images describing the most important objects and the history of the site. Six objects were identified and described in the article.

Irish Heritage Park - the article presented an overview of a non-existing heritage park in Ireland (see Figure 7). Details on the objects, their localization and the history of the site were given. The article consisted of about 500 words and 7 pictures. 9 objects were identified and described in the article.

All the images used in the articles were "snapshots" from the scenes presented in Copernicus to prevent the influence of the type of presentation (an animated scene in comparison to a real photo).

4.2.2 Participants

14 students, researchers and members of staff with normal, or corrected-to-normal, vision participated in the experiment. Three of our participants were female. The participants ranged in age from 21 to 36, with 7 participants in the 21-26 range and 5 participants in 27-36 range. 2 participants were MSc students, 8 had higher education, 2 were post-doctoral researchers. 8 stated that they very rarely or never use Wikipedia.

4.2.3 Procedure

In the experiment users were asked to read the sequence of 4 articles prepared for the purpose of the evaluation. There was no time pressure on the users, however, they were asked to behave naturally and not to spend more time than needed to read each article. To remove the effect of learning the order of the articles was different for each test. The order and the representation (Copernicus or MediaWiki) of the articles were random with the restriction on the complexity of the articles. In our experiment the complexity of the articles was growing from the less complex articles (Maya and Giza) to the more complex ones (both heritage parks). Two articles in each set were displayed using MediaWiki and two using the Copernicus system (one from each complexity group for both systems). After only one reading of the articles users were asked to answer a set of question about the content of the articles (see the next section). It is worth to highlight that the users were not asked to learn all the information presented in the articles. They were told before the reading that a set of questions regarding article content is to be asked afterwards.

4.2.4 Questionnaire

Our study involved interviews with the participants of the experiment. In order to measure users' satisfaction and to determine how much information users are capable of remembering using both representations a questionnaire was prepared. The questionnaire consisted of two parts. The first part was based on the Questionnaire for User Interaction Satisfaction (QUIS) developed by Shneiderman [Shneiderman and Plaisant 2004] and refined by Chin, Diehl and Norman [Chin et al. 1988] and was used to measure user satisfaction and overall reaction to the software for both systems. Each user rated both systems using a numerical scale from 1 to 7 with respect to multiple aspects, such as: reading characters on the screen, organization of information, learning to operate the system, system speed, etc. (see Figure 8 for an example).

Figure 8: *The section from the first part of the evaluation.*

In the second part the user was asked to answer a set of 14 questions about the content of the articles. Two types of questions were prepared: asking about spatial information (localizations of the highlighted objects) and significant facts concerning sites described in the articles (see Figure 9). Participants were asked to fill the questionnaire once they finished reading the articles.

> If you sit at the Jaguar throne what do you see in front of you?
> A) the skull
> B) the altar
> C) the chamber – I'm in the center of the pyramid
> D) something different
> E) I don't know

Figure 9: *The section from the second part of the evaluation.*

4.3 Results and discussion

In this section we present the results of the experiment in relation with the aforementioned evaluation questions. We performed frequency analysis on the results from the second part of the evaluation using Chi-square (χ^2) statistic to check their statistical significance. The results were used to answer the following first two questions. A summary of the results is shown in Figure 10.
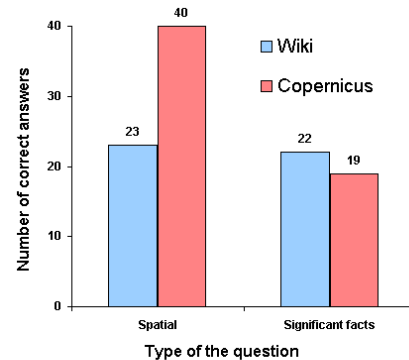
	Copernicus	MediaWiki	N	df	χ^2	Sig. Level
Spatial facts	40	23	30	1	4.97	.026*
Sig. facts	19	22	20	1	0.25	.61
Overall	59	45	52	1	1.88	.17

* Significant at the .05 level

Figure 10: *Chi-square statistic for test results (N - expected number, df - degree of freedom).*

4.3.1 Questionnaire

Question 1 - We wanted to determine whether binding hypertext with 3D scenes improves the visual and associative memory. We
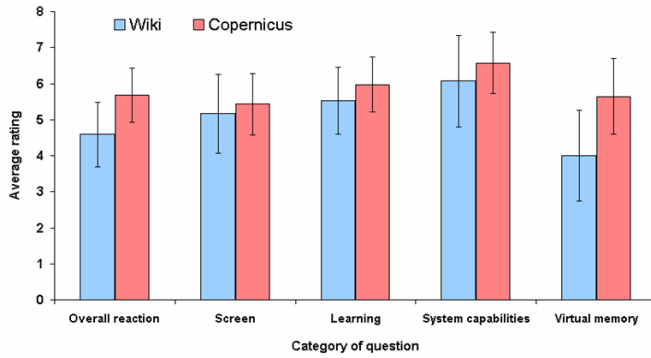
	Category	Mean	Std. Deviation
MediaWiki	overall reaction	4.59	.903
	screen	5.17	1.092
	learning	5.52	.922
	system capabilities	6.07	1.269
	virtual memory	4.00	1.256
Copernicus	overall reaction	5.69	.747
	screen	5.43	.852
	learning	5.98	.756
	system capabilities	6.57	.852
	virtual memory	5.64	1.046

Figure 11: *Evaluation Results - QUIS.*

have compared the total number and the percentage of the correct answers for both types of questions. In case of questions about significant facts presented in the articles, the results of all users were very similar; 22 correct answers were given in case of MediaWiki in comparison to 19 correct answers when using the Copernicus system (no significant difference). In the case of Copernicus we have noticed a significant increase of the number of correct answers to "spatial" questions, p=.026 (52% answers were correct in comparison to 30% when using MediaWiki, see Figure 10).

Question 2 - We wanted to establish whether the 2LIP model improves spatial cognition of presented information. We compared the number of correct results to the set of questions concerning spatial features of the localizations described in the articles for both systems. We noticed a significant difference - only 23 correct answers in case of MediaWiki in comparison to 40 when using Copernicus, p=.026 (see Figure 10).

Question 3 - We wanted to determine if the animated 3D scene in the background layer together with simple 2D-based navigation increases overall user's satisfaction level. We have compared the results from QUIS for both systems - the Wilcoxon Signed Ranks Test was performed to check their statistical significance (see Figure 11). In general, user found Copernicus more satisfying. Overall reaction to the system was ranked 1.2 points better for Copernicus than for MediaWiki, p<.01 (5.69 and 4.59 points respectively). Users found the system much more satisfying and stimulating than MediaWiki. On the other hand difficulty of usage and flexibility were ranked similarly. There was no significant differences in the case of screen (organization of information, reading characters on the screen) and learning (exploring new features, learning the system) categories. However, in all cases Copernicus was ranked higher, on average, than MediaWiki. Users pointed out that it was easier to remember placement of the objects using the Copernicus system. General impression on confidence was also higher, resulting in higher ranking in virtual memory category for Copernicus, p<.006 (Copernicus scored 5.64 points and MediaWiki 4 points respectively).

4.3.2 Summary

Statistical results are very promising. What is more, users' opinions on Copernicus were also in general very positive. One user stated, that he liked Copernicus because when the information is displayed in the background he didn't lose the context of the article he is reading (the text is displayed all the time in the same position, there is no need to switch to a larger image and back to text). Other user stated: "I find Copernicus more interactive (with the 3D animation in the background and the changes of vision when you

click on a link) and more pleasant. It is more similar to a game than Wikipedia, so more attractive." On the other hand some users found the animations too fast.

5 Future Work

There are number of future research directions we wish to explore. We would like to explore using automatic motion planning techniques that have been studied in computational geometry and robotics for more than three decades. We would like to use HoverCam [Khan et al. 2005] and/or ShowMotion [Burtnyk et al. 2006] interaction techniques for navigating around 3D objects at close proximity. We want to look at 3D Explosion Probe [Sonnet et al. 2004] that can provide access to the interior components of the model and enable spatial exploration.

If it comes to Copernicus, we want to make use of content that can be found in Wikipedia. Our system would be a new, web-based wiki engine that can play freely available content from this largest and most popular online encyclopedia. In compare to MediaWiki, users would be able to create 3D visualizations of the articles. We would also like to create the Rich Text editor that will provide users with an easier and faster way of creating new content. The other big miss is the inability to reverse the index in Copernicus and click on an element of the 3D scene and be taken to the relevant part of the article.

6 Conclusions

The World Wide Web as it stands today is an incredible success, which can be attributed to its simple architecture and an easily understandable document format (HTML). Its interface and structure is determined by the concept of the hyperlink, a directed relationship between two objects. We believe that links will remain the primary navigational means of the Web.

In this article, we have presented 2LIP - a new way for designing interactive 3D web applications. It is an attempt to create the new generation of text - it combines advantages of 3D experience with the advantages of narrative structure of hypertext. Our technique provides textual content with the spatial context of the 3D representation. Interaction with 3D layer is possible through hyperlinks in the upper, hypertext layer - our motivation was to simplify the 3D interaction style and adjust it to the Internet hypertext environment.

We introduced Copernicus, a prototype application that can be placed between Web 2.0 and Web3D. The evaluation has shown that due to only a slight modification of the current web brows-

ing, users had no problems interacting with this system. They have gained, however, by having a more entertaining style, which improved their spatial cognition and increased satisfaction. We believe that this kind of evolution is necessary to prepare people for the full-fledged 3D Internet.

* Images and videos that illustrate the research presented in this paper, evaluation materials, implementation details, and the user guide can be found at: http://copernicus.deri.ie.

7 Acknowledgments

References

ABASOLO, M. J., AND DELLA, J. M. 2007. Magallanes: 3d navigation for everybody. In *GRAPHITE'07*, ACM.

ANDREWS, K., AND PICHLER, M. 1994. Hooking up 3-space: Threedimensional models as fully-fledged hypermedia documents. In *MHVR'94*.

ANDREWS, K. 1994. Soaring through hyperspace: A snapshot of hyper-g and its harmony client. In *Eurographics Symposium on Multimedia/Hypermedia in Open Distributed Environments*.

BAUDISCH, P., AND GUTWIN, C. 2004. Multiblending: displaying overlapping windows simultaneously without the drawbacks of alpha blending. In *CHI '04*, ACM.

BEDERSON, B. B., AND BOLTMAN, A. 1999. Does animation help users build mental maps of spatial information? In *INFO-VIS '99*.

BELL, B., FEINER, S., AND HOLLERER, T. 2001. View management for virtual and augmented reality. In *UIST '01*, ACM.

BERNERS-LEE, T., HENDLER, J., AND LASSILA, O. 2001. The Semantic Web. *Scientific American*.

BOLTER, J. D. 1992. Virtual reality and the future of hypertext (abstract). In *ECHT '92*, ACM.

BURTNYK, N., KHAN, A., FITZMAURICE, G., BALAKRISHNAN, R., AND KURTENBACH, G. 2002. Stylecam: Interactive stylized 3d navigation using integrated spatial and temporal controls. In *UIST 2002*.

BURTNYK, N., KHAN, A., FITZMAURICE, G., AND KURTENBACH, G. 2006. Showmotion: camera motion based 3d design review. In *I3D '06*, ACM.

BUSH, V. 1945. As we may think. *Interactions (July 1996)*.

CARD, S., AND MACKINLAY, J.D.AND SHNEIDERMAN, B. 1999. *Readings in information visualization: using vision to think*.

CHEN, C. 2004. *Information Visualization: Beyond the Horizon*.

CHIGONA, W., SONNET, H., RITTER, F., AND STROTHOTTE, T. 2003. Shadows with a message. In *Smart Graphics*.

CHIN, J. P., DIEHL, V. A., AND NORMAN, K. L. 1988. Development of an instrument measuring user satisfaction of the human-computer interface. In *CHI '88*, ACM.

CHITTARO, L., RANON, R., AND IERONUTTI, L. 2003. Guiding visitors of web3d worlds through automatically generated tours. In *Web3D'03*, ACM.

COCKBURN, A., AND MCKENZIE, B. 2002. Evaluating the effectiveness of spatial memory in 2d and 3d physical and virtual environments. In *CHI'02*, ACM.

FEINER, S. 2002. Augmented Reality: A new way of seeing. *Scientific American*.

FITZMAURICE, G., MATEJKA, J., MORDATCH, I., KHAN, A., AND KURTENBACH, G. 2008. Safe 3d navigation. In *I3D'08*.

FORRESTER, 2008. Web3d: The next major internet wave.

FURNAS, G. W. 1986. Generalized fisheye views. In *CHI'86*.

GALYEAN, T. A. 1995. Guided navigation of virtual environments. In *SI3D'95*, ACM.

HALASZ, F., AND SCHWARTZ, M. 1994. The dexter hypertext reference model. *Communications*.

HARDMAN, L., BULTERMAN, D. C. A., AND VAN ROSSUM, G. 1994. The dexter hypertext reference model. *Communications*.

HARRISON, B. L., KURTENBACH, G., AND VICENTE, K. J. 1995. An experimental evaluation of transparent user interface tools and information content. In *UIST'95*, ACM.

ISHAK, E. W., AND FEINER, S. K. 2004. Interacting with hidden content using content-aware free-space transparency. In *UIST'04*, ACM.

JANKOWSKI, J., AND KRUK, S. R. 2008. 2lip: The step towards the web3d (poster). In *WWW'08*, ACM.

JANKOWSKI, J., IRZYNSKA, I., MCDANIEL, B., AND DECKER, S. 2009. 2lipgarden: 3d hypermedia for everyone. In *HT'09*.

JUNG, T., GROSS, M. D., AND DO, E. Y.-L. 2002. Annotating and sketching on 3d web models. In *IUI'02*, ACM.

KHAN, A., KOMALO, B., STAM, J., FITZMAURICE, G., AND KURTENBACH, G. 2005. Hovercam: interactive 3d navigation for proximal object inspection. In *I3D '05*, ACM.

NELSON, T. H. 1974. *Computer Lib/Dream Machines*.

RISDEN, K., CZERWINSKI, M. P., MUNZNER, T., AND COOK, D. 2000. An initial examination of ease of use for 2D and 3D information visualizations of web content. *IJHCS*.

RITTER, F., SONNET, H., HARTMANN, K., AND STROTHOTTE, T. 2003. Illustrative shadows: integrating 3d and 2d information displays. In *IUI'03*, ACM.

ROBERTSON, G. G., MACKINLAY, J. D., AND CARD, S. K. 1991. Cone trees: animated 3d visualizations of hierarchical information. In *CHI'91*, ACM.

SHIAW, H.-Y., JACOB, R. J. K., AND CRANE, G. R. 2004. The 3d vase museum: a new approach to context in a digital library. In *JCDL'04*, ACM.

SHNEIDERMAN, B., AND PLAISANT, C. 2004. *Designing the user interface: strategies for effective Human-Computer Interaction*.

SONNET, H., CARPENDALE, S., AND STROTHOTTE, T. 2004. Integrating expanding annotations with a 3d explosion probe. In *AVI'04*, ACM.

SUTCLIFFE, A. G., AND PATEL, U. 1996. 3d or not 3d: Is it nobler in the mind? In *HCI '96*.

WEINREICH, H., OBENDORF, H., HERDER, E., AND MAYER, M. 2008. Not quite the average: An empirical study of web use. *ACM Trans. Web*.