Visualising Knowledge Webs for Encyclopedia Articles

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Abstract

This publication presents a prototype visualisation system for navigation of encyclopaedia articles based on knowledge webs connecting articles to each other. A turning table is used as a metaphor to depict a result set as a whole, while three-dimensional objects of various shapes placed on top of the table represent individual encyclopaedia articles. The system employs a number of depth cues to enhance spatial perception and uses depth-dependent semi-transparency of labels to avoid display cluttering. A concrete implementation for the German language "Brockhaus Multimedial" electronic encyclopaedia is presented and discussed.

Keywords: Visualisation, Metaphors, User Interfaces, Interaction, Encyclopaedia, Java.

1. Introduction

An encyclopedia is a written compendium of knowledge which contains articles from many different fields. Most general encyclopedias are structured in an alphabetical manner and rely, in digital form, on keyword queries for locating specific articles and on link-based navigation for browsing articles. Knowledge maps connect articles with other articles of similar content, imposing a topical structure on the encyclopedia knowledge space without relying on a complete ontology of the knowledge space as a whole (which is often not available). This publication introduces a three-dimensional, interactive visualisation method for such knowledge maps and describes a concrete implementation for the Brockhaus Encyclopedia.

2. Encyclopedia

An Encyclopedia provides a rich repository of highly structured, annotated and revised information in the form of articles covering specific topics. Today's digital multimedia encyclopedias typically contain hundreds of thousands of articles which consist of textual content as well as images, sound and video. Information is usually reviewed and, in part, written by experts familiar with relevant knowledge areas. Digital Encyclopedias typically feature sophisticated search and navigation facilities to ease the task of locating and displaying specific articles.

The work presented in this publication is based on the Brockhaus Multimedial Encyclopedia [1], a product which enjoys a dominant market and image position in the German-speaking European countries (the famous German Duden is published by the same company). With around 240.000 articles and 350.000 mentioned keywords, Brockhaus is among the world's largest Encyclopedias.

2.1. Articles

Encyclopedia Articles always relate to a given keyword or concept: For example, and article could talk about "India", the "Roman Empire" or "Nuclear Power". Articles vary widely in size and detail, ranging from very short text segments which define a term only rarely used to reports of several thousand characters supplemented with images, audio and video for major topics. While an increasing amount of information in large Encyclopedias is of multimedia nature, the core information entity is still the textual article, which has often been revised and updated for a hundred years or more if a topic has a long history or relevance.

2.2. Metadata and Structure

A typical Encyclopedia article features at least some metadata which describes its content. Article metadata splits in three major categories:

- Technical metadata describes article properties like character count, number of revision or date of addition to Encyclopedia
- Content metadata provides hints on the articles content and context. For example, a topic can be assigned to each article, or a summary can be provided for larger articles
- Relational metadata describes relations to other articles, for example ontological links

With the presence of metadata, structuring of articles according to one or more attributes becomes possible. However, Encyclopedias are general-purpose knowledge repositories which can hardly be structured in a single, consistent way. Even if such a structuring could be devised, it would be highly susceptible to the personal preferences of editors. As a consequence, only superficial structuring is present in most Encyclopedias.

The Brockhaus Multimedial Encylopedia provides two metadata attributes particularly relevant for the work presented: Each article in the Encyclopedia is assigned a topic out of a collection of ten possible entries, including for example politics, history, science and art. Furthermore, articles are characterized as being of biographical, geographical or general nature. Both structurings have been taken into account when designing the visualisation described in this publication.

2.3. Knowledge Webs

The advent of ontologies has provided Encyclopedia producers with a promising way of introducing structure without having to resort to subjective subdivision of articles into topical hierarchies. However, as global Encyclopedias by definition cover the total of human knowledge, any matching ontology would have to be very comprehensive. While several attempts are currently in progress to devise such global ontologies [2], none of the available results is sufficiently powerful to structure an Encyclopedia as a whole.

Still, the Brockhaus Encyclopedia has taken a first step towards employing ontological structuring in the organisation of its articles: A Knowledge Web is present for most articles, which relates an article to a score of similar articles and provides a quantification of the degree of relatedness. While not an ontology in a classical sense, the Knowledge Web of an article allows quick identification of related content, and navigation can be used instead of search query refinement to browse a domain of knowledge.

Figure 1 The Gyro knowledge web visualisation about "India"

A Knowledge Web of a typical Encyclopedia Article contains around 25 related articles. The Knowledge Webs present in Brockhaus Multimedial are semi-automatically extracted in an offline process and manually edited, thus providing a very high degree of quality, as compared to links and categorizations derived fully automatically in an online process.

3. Visualisation

In cooperation with Brockhaus, we have devised a visualisation which specifically targets the Knowledge Webs present in the Brockhaus Multimedial Encyclopedia. The focus of our activities has been on replacing the currently rather formal, two-dimensional representation of the Knowledge Maps with a three-dimensional, metaphorical display more accessible and appealing to users. A visualisation system has been designed and implemented. Project results will be included in future versions of Brockhaus Multimedial.

Several visualisation techniques have been considered when planning for a visualisation of the Brockhaus knowledge web. Hyperbolic trees [3] are a widely accepted visualization technique for large link structures, of which a three-dimensional derivate has been described [4]. Unfortunately, hyperbolic trees focus on the visualisation of many links and objects at a time, while for the task at hand, a high-quality visualisation of comparably few objects was desired. Cone trees [5] display hierarchical structures as stacked cones arranged in three dimensions. However, the knowledge webs present in Brockhaus do not constitute a hierarchy and thus cannot easily be displayed in a cone tree. In addition, cone trees are prone to overlapping of object labels, which in the case of an encyclopedia visualisation would be particularly disturbing.

Still cone trees were considered as an alternative form of display for the ontological data attached to some of the encyclopedia articles as described in section 3.5. Further cues, including interaction metaphors and rendering hints, have been devised from visualizations such as Lighthouse [6] and Harmony [7].

3.1. Metaphor

Objects placed on a turning, multi-segment table have been chosen as a metaphor to represent the knowledge web. The table is divided into several sectors which represent topics. For each of the ten topic categories which articles in Brockhaus Multimedial are assigned to, a distinct sector colour has been chosen. Articles are represented as geometric objects, and placed on the turning table, in the sector corresponding to the topic they are assigned to; the central article the knowledge web corresponds to is placed at the table's center.

For further clarification, each object representing an article is coloured according to article topic. Another metadata channel, the type of the article, is encoded in the geometric form chosen for representation. Finally, so-called premium articles featuring voluminous content supplemented with multimedia data, are marked by a rotating "crown" constructed of semi-transparent triangles (any other visual accentuation could be used, however, the "crown" has been approved by users).

3.2. Object Rendering

Objects are rendered as solid geometry, with each object type having a distinct shape according to its corresponding entry type: Biographical entries are drawn as stylized characters, geographical entries are drawn as towers and general articles as cylinders. Object size in the visualisation reflects article size in the Encyclopedia.

Object appearance is enhanced by applying gouraud shading and supplying a projection shadow on the underlying turning table according to a light source placed in the top-left corner of the display, in accordance with the metaphor used in many graphical user interfaces. These measures also enhance depth perception, especially when the scene is animated. In fact, object hover slightly above the turning table, allowing the projection shadow to provide contrast of object edges against the similar-coloured table sector underground.

Figure 2 Article close-up, pop-up menu

Location of an object on the turning table is not related to inter-article similarity. The distance of an object from the centre denotes its relevance to the central article, and the placement of an object in a distinct sector relates the object to that sectors topic. However, two objects which are close to each other do not necessarily feature a close relation in content.

3.3. Label Rendering

Objects on the table have to be rendered with their respective article title. Title length can range from two characters to a hundred characters, an amount clearly not displayable with up to twenty objects on screen at a time. Consequentially, labels are cut off at a certain character count, and full label text is only displayed when a user points the mouse at a label. However, this measure is not sufficient to avoid the problem of overlapping labels which three-dimensional visualisations are prone to.

We address label overlap by applying a depth sorting to labels based on label anchor (object centre) z location in eye space. Consequentially, labels of objects in the foreground are drawn atop those of objects in the background. In order to retain at least partial readability for background labels, transparency is applied to label areas as a function of z: The further away a label is from the eye, the more transparency it gets assigned, with hard limits for very near and very far labels. Selected labels (labels the mouse is currently hovering over) always get zero transparency assigned, and are moved to the top of the z-Order. As a consequence, labels in the background of the scene do not clutter the display and obstruct visual objects, labels do not become immediately unreadable when even partially obstructed by another label, and selected labels are always perfectly readable.

A number of dynamic label layout algorithms are available, which could assign positions to labels completely avoiding overlaps. However, use of such algorithms would result in constantly changing label locations whenever animation is done or users change the point of view manually. User tests conducted in the context of the InfoSky project have shown us that users easily get confused by labels which change location even slightly [8]. Thus, labels have been positioned at fixed (three-dimensional) locations and are solely subjected to view and perspective transforms before displaying.

Figure 3 Sector selection pop-up

Labels for sectors on the turning table are handled differently from object labels. Sector labels are applied in a circular fashion to the outer edges of sectors by means of an appropriate texture mapping transform. Outer sector edges are flattened so that most of them remain visible at oblique angles of observation. Consequentially, even sector labels of sectors on the far side, as seen from the current eye location, are visible, even though they appear bottom-up. However, even an inverted view of a well-known text segment like a brief sector name provides enough visual recall clue to enable users to remember sector names quickly. User feedback indicated that though sector labels are ignored once users get familiar with the visualisation, they play an important role during familiarization with the various components.

If the point of view is placed low on the vertical axis, close to the turntable, a steep angle for the labelled sector edges would grant the best readability. However, if the point of view is placed (almost) top-down, flat sector edges would grant best readability. Experiments have been made with automatically adjusting the angle of sector edges according to current height of the point of view above the turntable. However, user feedback suggested that such dynamic modifications leads to a greatly reduced depth perception because unfortunately, they counter the perspective transform applied to the turntable. Consequentially, the appropriate feature has been dropped, and the sector edges are now fixed at an arbitrary angle.

3.4. Interactivity

Interactivity is provided through areas sensitive to mouse operations. Each object on the turning table displays a context menu: When the user places the mouse on the object’s label for a short time (less than one second, configurable), a menu appears atop the item offering options to centre the item in the view, to open the item’s referring article in the encyclopedia and to open the item’s ontology view. Each topical segment displays a 3D interaction area next to its label: Clicking this area expands or collapses the segment, displaying or hiding all object contained in the segment. Clicking on the surface of a segment (on a location where no object is placed) brings the segment to the foreground.

Interactivity not directly related to objects within the visualisation is implemented via popup menus: A number of menu headers are displayed on the screen edges, whenever the mouse enters such a header, the full menu pops up, overlaying the visualisation displayed. After selecting an item in the menu or leaving the menu area, the popup menu disappears again. The concrete layout (shape, colouring, texts, icons etc.) of the menus is subject to change, design is still in progress.

3.5. Animation

Transitions between discrete points of view within the visualisation are shown as animation sequences. This measure helps keeping the visual metaphor consistent and in providing users with a continuous world in which they can orient themselves. A typical animation sequence lasts about one second, with the exact duration depending on the total rotation and translation, in three dimensions, necessary to reach the desired destination point of view. Focusing on a sector, focusing on an article and displaying the ontology for an article (compare section 3.7) all trigger an animation sequence.

3.6. Environment Rendering

The environment of the turning table, is rendered using a cylindrical geometry onto which images matching the topics of segments are projected. For example, the segment “Kust” (art), when viewed from the table side opposite to it, displays in its background an image showing various statues, famous paintings, musicians and so on. Thematic background images are generally kept in the colour of the segment they back. Background images are blended against each other at their (overlapping) left and right edges, and are blended against the background colour on the top and bottom edges of the cylinder geometry forming the environment. We have experimented with using fog attenuation for background images and turning table. However, due to the highly varying angle of view, a fog configuration which enhances depth perception without hiding objects or looking unnaturally is very hard to find.

3.7. Displaying Ontologies

For a growing subset of encyclopedia articles, a backing ontology is available, connecting articles to related articles via directed, annotated edges.

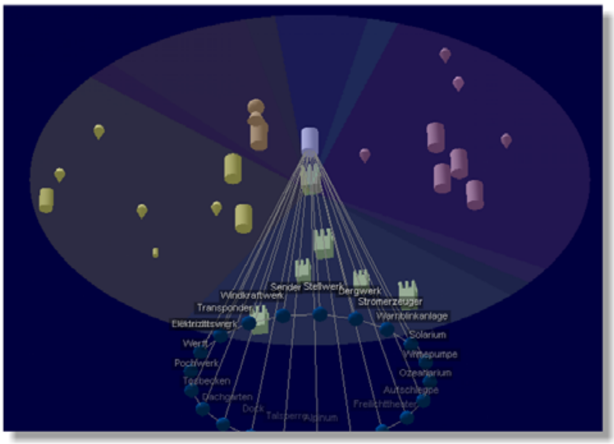

Figure 4 Experimental ontology display

While not the primary target of the visualisation discussed, such ontological relationships have to be represented to users in a convenient way.

Figure 5 Ontology navigation pop-up

An innovative visualisation metaphor has been considered in early prototypes, displaying related articles in the form of a tree below the plane of the disc (compare figure 4). However, due to problematic visibility of objects on the disc and significant extensions to already complex user interactions, this form of ontology display has been discarded and replaced by a conventional, textual tree view as shown in figure 4: For each article, a list of relations and related objects is displayed in a window hovering atop the object representing the article. Users can click on an entry to cause the visualisation to navigate to that entry.

4. Implementation

The system has been implemented using Java [9] version 1.5 as a development environment and the JOGL Java OpenGL bindings [10] as a graphical interface. All major brands of graphic accelerators are supported for OpenGL[11] rendering. Performance tests have shown that the system is fill-rate limited: When a graphics adapter capable of hardware rasterisation is present, realtime frame rates are achieved and processor load is just a few percent on standard office machines even when animation sequences are displayed. Due to the use of Java and OpenGL, the system is highly platform-independent: Distributions for Microsoft Windows XP, Linux and Mac OSX (there, using Java version 1.4) have been generated, which differ only by native library files required to bind to the platform’s OpenGL services. No advanced rendering features of OpenGL, like p-buffers or ARB extensions, have been used to further increase independence of platform and graphics hardware.

5. Evaluation

Formative user testing has accompanied the development process of the system presented. For example, quality and visual appearance of object labels has been evaluated in a prototype before being integrated into the system presented here, and visual design (layout, colouring etc.) is currently being adjusted to user feedback. Results of various other evaluations have already been integrated into the system. However, summative and comparative user testing remains to be done: An extensive user test comparing the flat knowledge web visualisation with the one presented in this publication is planned for 2005. Testing will includes multiple task assignments like locating specific articles or gaining an overview on topical distribution of a knowledge web. User behaviour will be recorded and noted by observers. Statistical data gained from records will be supplemented by interviews designed to gather qualitative assessments. We hope to be able to judge the improvements achieved with the new interface, and to get new research directions, from this user test.

6. Future Work

Future work will focus on evaluation: Extensive user testing and comparative system evaluation will be done in the near future to optimize all aspects of the visualisation presented. Advanced forms of displaying ontologies will be evaluated, to integrate ontology data more tightly with the current knowledge web. Finally, label rendering will be further optimized, with a label layout algorithm based on keyframe animation being envisioned as a promising approach.

Conclusion

This publication presented a three-dimensional visualisation system for knowledge webs consisting of encylopedia articles. A turntable metaphor employs visual attributes like object size, colour and shape to encode object metadata. Depth-dependent label transparency has been used instead of dynamic label layout to create a consistent display of textual object information. Extensive user tests will validate the concept in comparison with existing, flat systems in the near future.

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