

# UVA: 3D Representations for Visualizing Digital Collections

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## Abstract

**This paper describes UVA (U-DL-A Visualization Aid), a visualization tool that helps in the exploration of very large digital collections. This is made possible through representations of three-dimensional trees, which visually group categories or topics of objects included in a digital library. UVA also presents alternative solutions for various problems such as the manipulation of search results and multilingual access to collections, facilitating the user's comprehension and awareness of every aspect of the library. The system we implemented can be used practically from anywhere in the world, as it requires only a Web browser. This feature allows for learning and sharing of knowledge among scientists and the general public. UVA is part of an initiative termed U-DL-A (University Digital Libraries for All), which proposes open digital collections to be shared among universities. The paper also discusses results from usability tests as well as advantages and current limitations to be addressed by future work.**

## I. INTRODUCTION

Traditional libraries typically organize materials according to widely accepted schemes such as the classification system of The Library of Congress of the United States. In a digital library, however, this is but one of an infinite number of possible ways to organize collections. In fact, every user in a digital library could potentially devise one or more classification schemes to manage information from a personal point of view. Providing this flexibility, however, entails a variety of representational issues, both from the system and the user perspectives. From a system perspective, it is important, for example, to design data models to efficiently store and retrieve the structures that represent the various classification schemes. From the user's perspective, it is crucial to be able to navigate through the resulting complex space and to place information units in the context of one or more classification schemes. This paper focuses on the user's perspective. We describe "UVA", an interface designed to assist users in browsing and visualizing complex digital collections by providing three-dimensional representations and aggregation mechanisms for alternative classification schemes.

The paper is organized as follows: The following section discusses the general digital library context in which this

research has been undertaken. Next, we refer to the specific navigation problems posed by the complex navigation spaces in our digital library. Then we present UVA, the solution we propose to address these problems. We discuss the design decisions made in the the design of UVA Then we present UVA, the solution we propose to address these problems and how was implemented. We also discuss briefly the usability of this visualization interface. Finally, we provide an overview of ongoing and future work.

## II. THE U-DL-A DIGITAL LIBRARY

University Digital Libraries for All (U-DL-A) is an initiative to explore the issues in the development of digital libraries [12] for supporting undergraduate and graduate education. U-DL-A has been undertaken in the context of an actual library serving a community of students and researchers. U-DL-A builds upon ongoing work on the definition of architectural components for distributed digital libraries as well as work on user interfaces for managing large information spaces. Over the past three years, our group has developed a system architecture for a digital library that addresses the needs for communication, collaboration and information management among a highly distributed community of users [1,4,5,6]. U-DL-A meshes traditional and digital library services by providing a seamless environment for patrons. The U-DL-A digital library is conceived of as incorporating major advances in the field and at the same time serving as a testbed for exploring open research issues.

## III. NAVIGATION SPACES IN U-DL-A

We have started the construction of various digital repositories within U-DL-A. At present, we have focused our efforts on three collections: Digital Theses, Presidential Correspondence and University Publications, which we describe next.

### **Digital Theses**

Among the most interesting digital collections that have been created in various institutions of higher education around the world are those of theses and dissertations (see,

for example, [7]). These are formal, original and novel investigations that present critical analyses, diagnoses and solutions to problems in specific areas of knowledge. Students and researchers consider these a valuable information resource.

Our digital theses collection will include both undergraduate and graduate works. We have started the construction of this collection (see <http://biblio.udlap.mx/tesis>) by incorporating theses of one pilot academic department which already has a digital thesis requirement according to the guidelines developed by our library. All university departments are expected to establish this requirement during next year.

#### **Presidential Correspondence**

The personal archive of Porfirio Díaz (Mexico's President from 1876 to 1911) is one of the most important original information sources of Mexico's modern history. A total of 663,843 manuscripts and telegrams, many of them encrypted, form this special collection under our custody. As part of this collection, our library holds microfilmed copies of approximately 70,000 telegrams generated during the Díaz administration. We have started a project for the digitization and decryption of telegrams to make them widely available in an organized fashion (see <http://biblio.udlap.mx/telegramas>).

#### **University Publications**

During its more than 50 years of existence, our university has generated a very large number of publications, both for external and internal use. A project has been initiated to construct a University Publications Collection (CPU), which integrates present publications (already generated in digital formats) with all previous publications available in the institutional archives.

#### **Physical Collections**

In addition to the digital repositories, navigation in U-DL-A also considers the University Library's physical collections, available via a conventional on-line catalog. These collections comprise some 520,000 items including books, magazines, maps, microfilm, and others.

### IV. NAVIGATING THROUGH MULTIPLE TAXONOMIES

One of the fundamental aspects that distinguishes a digital library from its conventional counterparts is its enormous potential to make an otherwise complex dynamic collection manageable. Of particular interest for U-DL-A is the problem of navigating around information spaces in which multiple taxonomies coexist.

To illustrate the problem, consider, for example, a user who is exploring the area of Human-Computer Interaction (HCI) in the library. In the Dewey Classification System, the user would begin by looking at a category labeled "General." After following three different levels down the classification tree, the topic of interest would be found and the user could browse related materials.

Alternatively, the taxonomy in use could be the one suggested by The Library of the Congress. If users are familiar only with the Dewey System, it would be difficult to find a topic such as HCI. A user could assume the branch to follow could be "General Works" (A) rather than "Science" (Q). A similar problem will occur if we start with the Library of Congress taxonomy and then we try to access information via the Dewey System. In addition to this, users should be able to generate their own classification systems. For example, a student could prefer to organize materials and in general view the library from the perspective of the courses taken every semester.

Multiple taxonomies can be made available to users of digital libraries so they utilize those they find more convenient. However, the complexity of information spaces increases dramatically when we consider the existence of multiple taxonomies. Not only can navigation be cumbersome, but it could also become very difficult for the user to be aware of the available taxonomies and the context in which a given information unit can be placed. It is necessary to devise mechanisms to provide orientation for users in these complex information spaces, and also means to visualize the organization of data in graphical form. It is particularly important to provide access to multiple taxonomic perspectives and the relationships among them.

### V. UVA: VISUALIZING COMPLEX INFORMATION SPACES

Most navigational interfaces to existing digital repositories organize information hierarchically. Users are presented with textual or graphical items in a 2-dimensional space from which links can be followed (in a depth-first fashion) to related materials. Additional links between different branches of a given hierarchy allow the user to navigate through very large taxonomic trees. Given the additional complexity introduced by multiple taxonomies, alternative interfaces and representations mechanisms need to be designed.

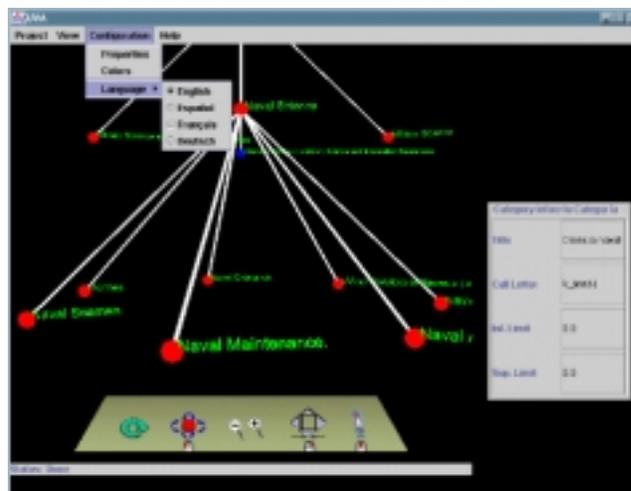


Figure 1. UVA's interface.

## Introducing a 3D Browser for Complex Spaces

UVA is based on 3D representations of hierarchical structures to visualize overlapping classification schemes. It allows users to start browsing the library from a default taxonomic point of view, which is represented graphically as a three-dimensional tree. As nodes (representing groups of library items) are selected, taxonomic sub-levels and their relationships with other existing taxonomies are displayed. The user can zoom in and out in this 3D representation, as well as rotate each taxonomic tree, thus keeping a sense of the context in which navigation is taking place. From any node in the 3D trees, users may obtain associated information, such as full bibliographic citations, abstracts, tables of contents or full documents in a variety of formats and media.

We now discuss three aspects of the collections that have played a central role in the design of UVA: volume, complexity and dynamism. We then present the decisions we made when designing the 3D browser.

### Volume

Browsing in the digital library invariably takes place in the context of very large information volumes. For example, if someone wants to check books on computer science at UDL-A, 4,242 items will appear. If the books we are interested in are about electronic and electrical engineering we would end up dealing with 10,693 items. If we try Mexican History, around 10,000 books plus 70,000 telegrams are available. Browsing through very large sets of information is well beyond user capabilities.

### Complexity

Hierarchies are used to provide a simple mechanism to organize large sets of data. However, multiple taxonomies introduce a level of complexity that cannot be dealt with easily in the user interface. There are several cases that need to be addressed in this respect: the same item can be classified by different authors under different categories; an item can be considered to actually consist of more than one taxonomic group or, conversely, multiple items can be regarded as a single group. This brings about a number of nomenclature and representational implications. For one thing, representing multiple overlapping taxonomic trees in two dimensions does not result in an intuitive way to view data relationships.

### Dynamism

The repositories in the digital library are constantly changing and growing. Not only is new data made available, but also new categorization policies and new taxonomic points of view need to be included in the digital library. The repositories are highly dynamic and these changes need to be reflected in the interface in a visual way so as to increase user awareness of the library's dynamism.

## Design Decisions

In order to address the problems of handling multiple taxonomies in 2D space, we decided to explore the potential of a user interface based on information visualization and overlapping three-dimensional trees. 3D representations of hierarchical structures should allow users to navigate around existing taxonomies, transforming an otherwise abstract and unwieldy structure into a tangible and manageable medium.

The problem of information volume is addressed by allowing users to group tree elements according to their needs and preferences. Users can delimit the information related to the items being studied and eliminate information that is not relevant. Considering that a user typically can manage sets of cardinality in the range of  $7 \pm 2$  elements in short-term memory [14], we limited the number of elements displayed at a given taxonomic level to a maximum of nine subsets. If, say, a group has 63 subsets, a tree representation in UVA will show seven nodes at the subset level. When a user selects one of the subset groups represented by a tree node, that node will explode to show the subsets it contains, while the other nodes at the same level will shrink to maintain a manageable number of nodes on display. The same policy will be applied while the number of elements at any time is larger than nine. Every node is labeled with either a specific item name or a range of items names (alphabetical ordering is assumed).

The issue of information complexity is addressed by allowing users to view trees from a vantage point when zooming out, or getting closer to nodes of interest when zooming in. The nodes at any taxonomic level can also be rotated to facilitate locating specific items names. Nodes are also colored to avoid user disorientation during navigation and to help differentiate subset nodes from terminal named items, and shrunk subset nodes from newly exploded elements.

## VI. VISUALIZING THE INTERFACE

This section provides an overview of the interface (Figure 1) designed to allow users to visualize large repositories as 3D trees.

### Trees

When users start navigating through the library, they are presented with the first level of the tree (Figure 2). At this point, all categories are aggregated into a manageable number of up to seven groups (grouping factor). Considering that the Classification of the Library of Congress includes 21 basic categories, the first level includes seven groups containing three subsets of categories each.

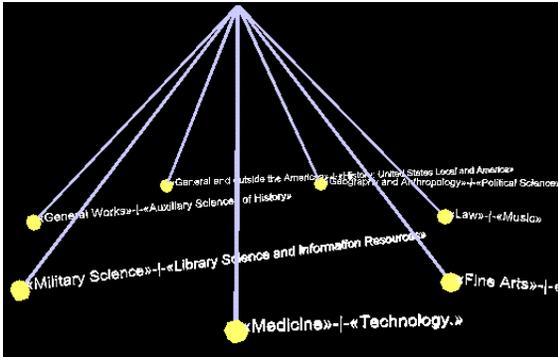


Figure 2: Three-dimensional tree

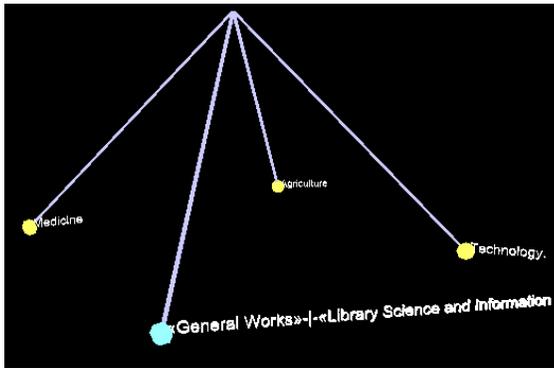


Figure 3: Explosion of front node "Medicine-Technology"

When the user selects one of these nodes, the elements it contains are displayed (Figure 3) and all the other groups are collected into only one node, which is marked with a different color to facilitate user orientation. This policy is applied as long as the number of elements at contained by any selected node is larger than the grouping factor. When the user selects a node containing fewer categories than the grouping factor, the next level can be displayed.

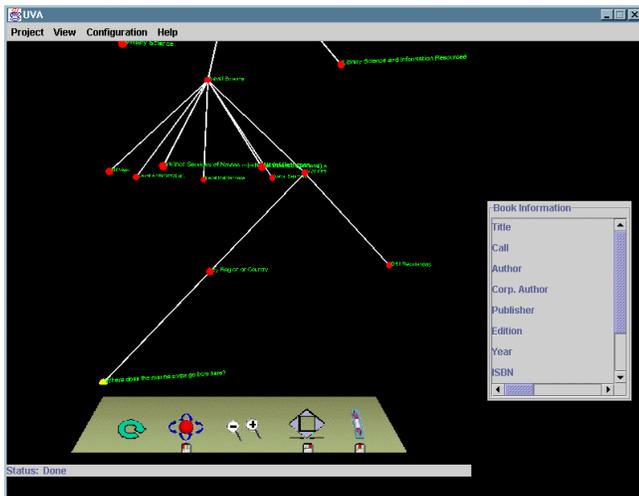


Figure 4. A specific book is found using UVA.

At the final level each node is associated with its bibliographical information (Figure 4). In future versions of

UVA users will be able to obtain summaries, content tables, indices and full documents in a variety of formats and media.

### Browsing

As noted earlier, the issue of information complexity is addressed by allowing users to view and to manipulate trees. This is accomplished by providing Browsing Control Panel (see Figure 5), which can be used to zoom in and out of nodes of interest. At any taxonomic level, trees can also be rotated to facilitate locating specific item names. This control panel also allows the user to manipulate the entire 3D representation by rotating, getting closer, enlarging or moving it.



Figure 5: Browsing Control Panel (reload, rotate, zoom, move up-down-left-right, move backward-forward)

### Other Features

UVA includes a number of additional features to facilitate user interaction with large collections:

- Configuration: Users can customize the grouping factor as well as the color and size of tree nodes and branches.
- Sound: Sounds [2] alert the user and provide feedback about actions carried out using the browsing control panel.
- Multilanguage Interaction: Four languages were included to facilitate access to the collections (Spanish, English, French and German)

## VII. UVA IMPLEMENTATION

This section focuses on how 3D trees are created and how the interaction with the user has been designed. The description of the processes involved in generating and maintaining a collection of over 200,000 bibliographic records and 5,000 categories is beyond the scope of this paper.

In order to make our 3D browser as widely available as possible, we relied on Java3D, a multiplatform solution based on OpenGL [16], which is becoming a defacto standard in 3D imaging. Java allows users to access the 3D viewing facilities through a regular Internet browser such as Netscape Navigator or Microsoft Internet Explorer.

In the visualization tree, every node (a geometric sphere) is associated with a data structure also in tree form. In fact, there are two trees in the system:

- 1) The graphical representation of hierarchies that the user can manipulate freely.
- 2) The data structure that makes use of the inheritance paradigm in object-oriented programming and which is not seen by the user; this tree keeps all the information retrieved from the database.

This data structure is defined as follows:

```

UVA_Node
{
  Node Type (document, group, backnode)
  Node Information (label-title, range,
  author, etc)
  Paintable (if this node (and their children)
  must be painted when the whole tree is
  painted)
  Node Coordinates (spatial x,y,z postion of
  the node)
  Node's Father (the category node that
  contains current node)
  Node's Children (subcategories or
  documents of this Node), in fact it is an
  UVA_Node linked list.
}

```

An interesting feature related to how a tree is built, considering the need to maintain database connections open, is that data are retrieved from the database as the users traverse the navigation space. Each time the user explodes a node down to a lower level, complete categories or document groups are retrieved, thus keeping a balance between current and existing requests, optimizing memory usage.

### Drawing 3D Trees

#### General algorithm

In order to draw the branches of the tree dynamically we rely on a recursive algorithm that defines the coordinates of each branch and its children. Upon exiting the recursion, an updated tree is completely rendered on the "virtual universe." The general algorithm is indeed similar to the well-known Depth-First Search algorithm used to traverse acyclical and directed graph [15]. Figure 6 shows an example of the order in which nodes are painted.

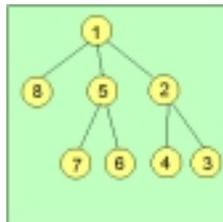


Figure 6: Order in which nodes are painted.  
Branches

In order to draw each of the tree branches, we extend a procedure introduced by the Cone Trees project ([10], see Related Work). This procedure consists of tracing the branches on the imaginary surface of a cone, calculating distances based on its height, radius and generatrix (Figure 7). As mentioned previously, this is done recursively, so upon exiting an initial coordinate (parent node) one should know the spatial position of the branch end (child node). These values are obtained as discussed below.

Using the values provided by the user for branch length (cone's generatrix) and opening angle (Figure 7A), it is possible to calculate the remaining elements using the Law of Sines [9].

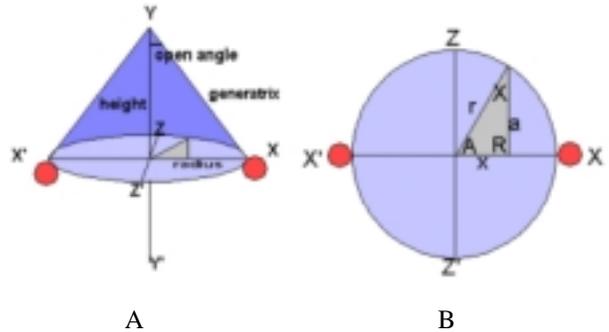


Figure 7. Branch-Cone Relationships.

Now, having calculated the new Y coordinate we can analyze Figure 7B to obtain the X and Z coordinates of the node (again, applying the Law of Sines):

$$\frac{x}{\sin X} = \frac{r}{\sin R} = \frac{a}{\sin A}$$

Where A is the angle on the circumference for each branch, dividing the 360 degrees by the grouping factor and multiplying it by the index of the node, and r the radius of the cone:

- A = angle per branch \* index
- r = radius
- R = 90 = PI/2
- sin R = 1
- a = (r \* sin A) / sin R = r \* sin A
- x = (r \* sin X) / sin R = r \* sin X
- X = 90 - A

Finally we have calculated 'a', which intuitively can be seen as the Z coordinate. Similarly x is the X coordinate of the current node and branch to draw. Now it is just necessary to add these calculations to the parent node's coordinates so that the child node can be drawn at the right place in the virtual universe.

#### Grouping

As for node grouping, the algorithm we used is quite simple, as can be observed in the following pseudo-code:

- 1) Divide the retrieved subcategories number by the grouping factor (default is 7)
- 2) If quotient > 1
  - a. Create as many "auxiliary" nodes as the grouping factor
  - b. Move the subcategories number given by the quotient to each created node.

c. For each transferred node apply this code recursively.

Else the nodes remain unchanged

Another special consideration is made when the result of the division is not an integer number. In this case the last child node is an auxiliary node created to contain those nodes in the remainder part of the division.

In order to clarify this, let us consider an example: If a node has 25 children (subcategories), and the grouping factor is 7:

25 divided by 7 gives us 3 children for each node plus 4 remaining nodes

7 auxiliary nodes will be created whose function is to contain 3 nodes each.

Each auxiliary node will have a number of children equal to 3

The seventh node will contain 4 children in addition to its 3 "natural" children, with a total of 7 children for this last node.

The time function used by this procedure is:

$T(n) = 27n + 16 + \text{GroupingFactor} * T(n/\text{GroupingFactor})$   
that in order to simplify calculations it would be expressed as:

$T(n) = n + \text{GroupingFactor} * T(n/\text{GroupingFactor})$

Its Complexity Order [15] is:

$O(n \log n)$

### Exploding Nodes

When the user selects a node that aggregates other nodes the expansion procedure is as follows:

- 1) An auxiliary node is created and will represent the nodes and levels currently visible for the user
- 2) The group of sibling nodes (same level) of the selected node become the new children of the node just created
- 3) The node just created is added as parent of the selected node
- 4) Children of the selected node are copied by reference and become also children of the parent of the selected node.

Graphically, this procedure is illustrated in Figure 8. Here, the selected node is node number 3, which is an aggregate of nodes 6 and 7 (i.e. Categories 6 and 7 actually belong to the same level as the rest of the nodes, only they are hidden inside of node 3 to maintain a manageable number of nodes. Nodes 6 and 7 will be displayed when node 3 is selected (exploded). Node A in Figure 8b refers to the new auxiliary node created in Step 1 of the expansion procedure. Figures 8c-d shows how nodes are rearranged internally according to the procedure just described, whereas Figure 8e illustrates the new tree as displayed to the user.

Later on, if the user selects node A to go back to the previous state, the process is reversed.

The processing time of this task is constant (14 time units). Due to the fact that categories are retrieved at the user's request, it would be necessary in some cases, to add the time needed to process the database query plus the time needed to group the requested categories or documents.

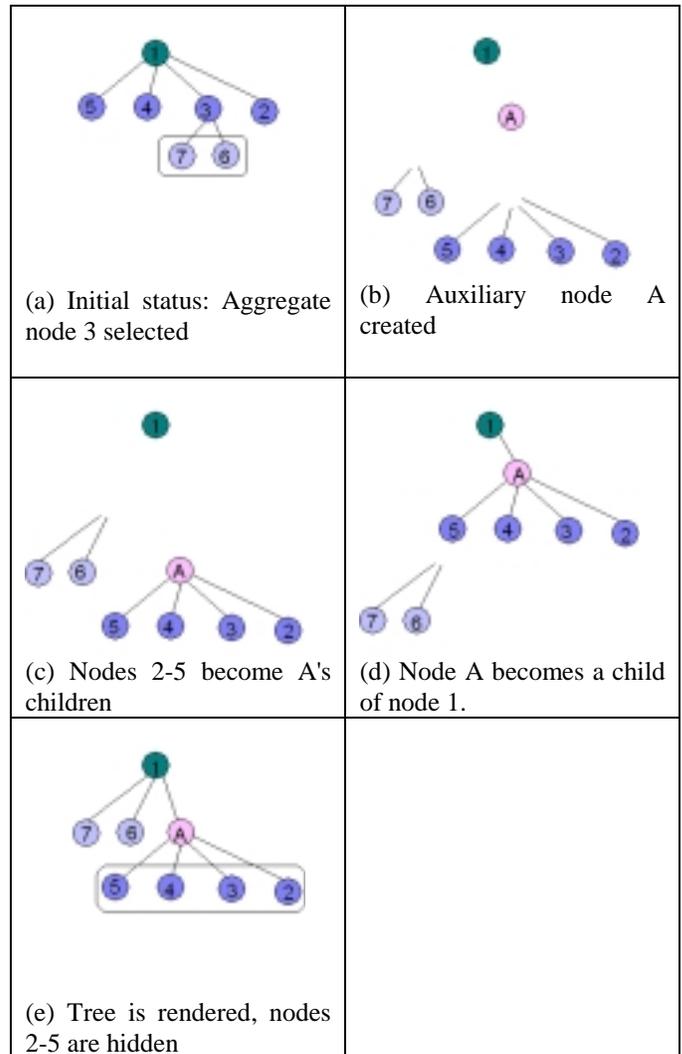


Figure 8. Node Explosion.

## VIII. EVALUATION AND RESULTS

In order to assess the potential of UVA, various usability tests were carried out with real users. After a brief demonstration of UVA and a 5-minute explanation about its functionality, users were asked to carry out 3 basic tasks following in the following order:

Finding a category in the default classification (this required manipulating the tree by using the browsing control panel)

Personalizing colors of nodes and branches

Restoring the tree to its initial state.

Users were given 5 minutes to perform these tasks. 70% of the users were able to perform at least the first two tasks. By analyzing comments from the users we also derived the following:

The browsing control panel as initially presented was confusing for some users. For example, pressing the right arrows moved objects to the right of the screen, whereas what the users wanted was to see objects that were hidden to the right. UVA's behavior was modified accordingly.

In addition to the information available about documents, a map or some reference to the physical location of the documents was requested by users to facilitate the process of visualizing the physical arrangement of objects in the library.

Users were excited about the possibility to visualize full documents in different media. Some of the projects in U-DL-A focus on digitizing collections to make this possible.

In general, users found UVA novel and interesting, and they thought it will be helpful for document browsing.

Some additional benefits and advantages of UVA include:

It provides a complete different perspective for the visualization of the resources in a library.

It assists users in the task of structuring the navigation of a large information space, as it presents all the available information categories and related resources, inviting the user to explore an otherwise unstructured information space.

The grouping algorithms, graphics techniques and the general model can be easily adapted for other digital collections.

Java3D proves to be an excellent graphics tool. Scene compilation and rendering are accomplished with acceptable performance.

Some of the applications of an interface such as UVA include:

**Access:** Certainly the main application of UVA is that presented in this paper, being an interface for visualizing the huge volume of information managed by digital libraries.

**Administration:** When the system was demonstrated to some library staff members, some mentioned that an interesting application would be the a system for librarian based on the same principles of UVA. This system would allow librarians to place a document in the collection by inserting it directly into the 3D tree. Additional functionality includes validating appropriate classification by checking whether all the works by a specific author have been places in the same branch.

**Software development:** UVA could help system developers in organizing software components, including their different versions and inter-relationships.

## IX. RELATED WORK

UVA builds upon techniques explored by related work on visualization and information retrieval. We provide some pointers to our previous research and to related work by other research groups.

Previous research

### **Agents as Guides for Multiple Taxonomies**

We have designed and prototyped several library services and user interfaces for a specific application domain (botany) [1,4,5,6]. In the area of visualization we have designed an environment in which agents act as guides for users, alerting them on the existence of alternative taxonomies and assisting them in the process of navigating through a multi-taxonomic botanical information space [11]. In this environment, agents called "mutants" offer to guide the user through the repository using their particular point of view. Each mutant agent presents the user with an alternative path to continue browsing the library.

### **3D Tree**

Although Mutant agents improve user awareness about existing alternative classification schemes, users still find it difficult to navigate around multiple taxonomies and to visualize the underlying information space, as they can view only one taxonomy at a given time. In order to address these problems, we developed visualization tools for very large information spaces. We started by working on 3DTree [1], a graphical browser intended to supplement Mutant agents in the context of the Floristic Digital Library. We then realized the concepts introduced by Mutant and 3DTree can be applied more generally to provide access to multiple classification schemes in digital libraries. Thus we incorporated this development to our university digital library as the U-DL-A Visualization Aid (UVA).

External research

### **Conetrees**

Conetrees [10,3] are tridimensional representations of hierarchical information. Their main purpose is the optimal utilization of the screen and the possibility to display the entire structure at one time. The root node is localized in the cone's apex and all their children are placed at the circular base of this 3D cone; any node can be viewed at front rotating the the tree.

### **Reconfigurable Disc Trees**

Reconfigurable Disc Trees (RDT) [8] are an improvement on Conetrees, preserving the same features but with the additional characteristic of using different shapes as cones can be transformed into plane discs.

## X. FUTURE WORK

### **Synthetic Agents**

Lifelike characters seem to be a natural addition to UVA's three-dimensional environment. These synthetic agents [13] could communicate with the users interested in navigating through classifications and providing guidance or assistance in different tasks.

### **Multiple Collections**

Currently, UVA is limited to only one collection (the library's online catalog), as U-DL-A collections are still

under construction. We will be working on system extensions to support multiple digital collections.

### Filtering

Another desirable feature to be incorporated into UVA is the ability to change UVA's point of view and personalizing the information universe to suit the user's favorite authors, preferred publication dates, publishers or conferences. In this way the tree would be pruned, clipping those branches known as uninteresting for the user.

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