Design Principles for Navigable Information Spaces

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Abstract

Navigation has become an increasingly useful way to describe how users interact with large information spaces, yet little guidance is available indicating how to design spaces to facilitate navigation. This paper presents a set of design principles for constructing navigable information spaces, principles we have collected from the study of real-world information spaces, and shows how to apply them to design a browsable space of university subject listings.

Content Areas: Knowledge Representation and Reasoning/Tasks or Problems/Design or Modeling or Simulation or diagnosis, Knowledge Representation and Reasoning/Tasks or Problems/Spatial and geometric reasoning
Tracking Number: A320

Introduction

The increasing quantity of information available on-line has challenged designers and researchers to discover new ways to organize and present that material. As the size of on-line collections grows, two kinds of constraints on interaction become dominant. The first kind concerns the limitations of technology to store, transmit, and display data, limitations of network bandwidth, processor speed, and display resolution. Although these limitations will always be relevant despite constant improvements in technology, we believe a second category of constraint matters even more: those arising from the cognitive architecture of the human mind. Simply put, our hardware grows exponentially faster, but our cognitive and perceptual abilities remain essentially unchanged. One consequence of this is the difficulty users find in making successful interaction decisions in information spaces, where it is often difficult to browse, retrieve, and make sense of the information architecture. The essential problem was described with great clarity nearly thirty years ago when Simon, discussing the information overload brought on by computers, suggested that "a wealth of information creates a poverty of attention" (Simon 1971).

It is this second limitation we address here, by exploring navigation as the organizing metaphor for describing and designing information spaces so that they stay within the cognitive information budget.

In such a system, information seeking becomes a process of wayfinding, navigating through an information space. Our central thesis suggests that the design of an information space is well served by aiming for five design goals: (i) a space should gives the user a *sense of place*, i.e., the knowledge of where he is, allowing him to remain oriented; (ii) a space should give the user a *sense of space*, i.e., knowledge of where he can go, allowing him to make correct navigation decisions; (iii) content should be arranged (spatially) according to organizing principles communicated explicitly to the user, a sort of legend for the spatial properties of the space; (iv) navigation can be significantly enhanced by employing analogues of affordances used for navigation in the physical environment, such as *maps*, *signs*, *paths*, and *landmarks*; and finally (iv) the affordances should be mapped to the content of the space in a way that aligns with the semantics of the content.

To understand how these goals can guide the creation of navigable information spaces, we have studied urban design (e.g., Lynch 1960) and the design of real-world information spaces: places where people navigate to acquire knowledge, such as educational museum exhibits. From this study, we have articulated design principles indicating how navigation affordances from the physical domain can be used in an information space. This paper gives examples of spaces that have been designed with these goals in mind and provides a sampling of the design principles we have collected that aid in meeting the goals.

Navigation in Information Spaces

A user's view into a information space can be thought of as a window showing a small part of the available information and a set of moves that permit the window to change from one view to another. The kinds of views and moves available depend on the particular organization and interaction paradigm chosen for the space.

For example, a user's window into a traditional hypermedia system might consist of a view of the document at the current node, with possible moves indicated by links to other nodes.

Users of hypermedia systems frequently experience difficulty in locating the resources they need, becoming disoriented and confused about the next move to make, sometimes called the "lost in hyperspace" phenomenon (Edwards and Hardman 1993). This is due in large part, we believe, to a lack of informed design of the space and lack of navigational affordances, particularly of the sort found in the physical environment.

Mental and Conceptual Maps

Research in how people represent their environments (as *mental* or *cognitive maps*) has found that subjects frequently recall particular features, such as landmarks, paths, and regions and that they use these effectively for navigation (Lynch 1960). We suggest that if these same features are used to organize and present an information space, users will be able to construct an effective mental map of that space as well.

If, in addition, these features are not assigned arbitrarily, but are instead assigned according to an organizing principle that reflects useful relationships in the knowledge domain, this mental map will reflect the conceptual relationships in the collection – it becomes a *conceptual map* of the domain (Lokuge, Gilbert and Richards 1996).

An Example Information Space

As an early example of how an information space might be designed around some these concepts, we designed a space containing a collection of research articles published on-line in the Journal of Artificial Intelligence Research (Figure 1). We grouped them into *regions* based on the subtopic of AI they address, provided senses of *place* and *space* with a controllable viewpoint over the article collection, and informed the user of this organization with explanatory documentation and text labels. The positive responses from users of the system led us to consider the general problem of designing information spaces for navigability.

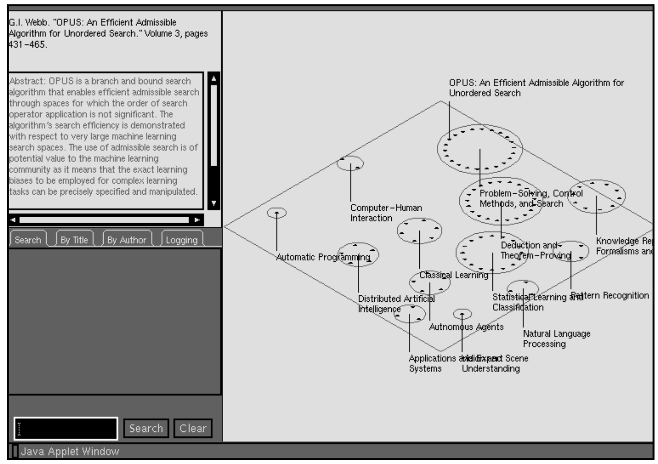

Figure 1. The JAIR information space.

Design Principles for Information Spaces

That design problem could be stated as, *given a collection of knowledge and a set of tasks, how do we select organizing principles for the space and assign navigability features to elements in the domain?*

The search for these design principles motivated the study of educational museum exhibits, particularly the sort found in science and history museums, whose purpose is both to educate and entertain the visitor.[1] In analyzing these exhibits, we tried to understand how the material in the exhibit was organized and how navigability features were used to guide the visitor through the space.

These physical information spaces have many of the properties desired in virtual information spaces. Their designers decide on an organizing principle for the material and situate it in a physical space, adding navigability features as needed to guide the visitor through the exhibit. Visitors should never feel disoriented or lost in an exhibit, and should be able to understand the organization of the material surrounding them.

Although many of these principles are not novel, we suggest that because they have proven effective in the organization of physical information spaces, they can be applied to create navigable virtual information spaces. Users can then navigate a knowledge domain by knowing how to navigate in physical spaces.

Principles for Organization and Communication

The first group of design principles indicates how exhibit planners organize material to make it coherent and understandable. They can be thought of as organizing principles for a virtual information space, which have already been used successfully in a physical exhibit space.[2] (Some are familiar because they have been used successfully in good writing and speaking.)

Principle 1. Organize the presentation around a hierarchy of messages. This principle represents a commitment to design based on what the visitor should take away after a visit to the space. The concepts to be communicated are stated as messages and organized in a hierarchy. Messages nearer the top are fewer in number but are the most important to communicate; they contain the concepts the viewer should understand to make sense of those lower in the hierarchy. Messages lower in the hierarchy, in turn, should justify and elaborate those higher in the hierarchy. This principle was used to help plan the 1997 Leonardo exhibit at the Museum of Science, Boston, and is discussed in (McLean 1993). Part of the message hierarchy for Leonardo is shown in Figure 1.

Principle 2. Use a constantly evolving attribute of the material to sequence it along a path. Time and place are two common attributes used to sequence material in this fashion. Time places the material in the context of external

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[1] We did detailed design studies of: the Leonardo exhibit at the Boston Museum of Science, and exhibits at the John F. Kennedy Museum, the National Air and Space Museum, the National Museum of Natural History, and the U.S. Holocaust Memorial Museum. We interviewed the designers and planners of the exhibits and collected primary design documents for the exhibits, including literature on museum exhibit planning and design.

[2] Space does not permit all of the principles to be discussed, or the contents of the exhibits studied to be related in detail. Complete descriptions can be found in (Foltz 1998).

events and can illustrate causal relationships between events. Navigating through time by traversing a spatial timeline can create a narrative: a story to tell, perhaps communicating the messages outlined in the first principle. This was used to order a series of biographical exhibits at the John F. Kennedy Museum.

Principle 3. Order the concepts so earlier concepts facilitate the understanding of later concepts. This principle, well known in lecturing and course design, can be applied by dividing the content into a series of concepts and determining the partial order that indicates which concepts need to be understood before others. That diagram also indicates a set of feasible paths through the space that present the material in a learnable fashion. We found it employed effectively in the *Origin of Species* exhibit (Miles et al. 1988).

Principle 4. Provide a memorable introduction and conclusion. This principle (also well known in lecturing) emphasizes the importance of the first and last things the visitor sees. Introductions create expectations about what is to come, while conclusions unify and clarify what has been seen. Of key importance is that they should serve the larger intent of the exhibit, and be consistent with its organizing principle. Many of the exhibits studied used their introductory or concluding portions for these special purposes; for specific examples see (Foltz 1998).

Principle 5. Allow for multiple levels of engagement and understanding. This principle accounts for differing levels of interest visitors may have. For different parts of an exhibit, the visitor acts as a reader, consuming everything in front of him; a browser, picking out details and pursing those in-depth; and a skimmer, noting the obvious and moving on. Visitors can take something away from a part of the space no matter the amount of time they spend. This principle is discussed in (Miles et al. 1988).

Principles for Navigability

In addition to organizing content in an educational and informative way, exhibits are (or should be) navigable spaces - it ought to be easy to find your way around without getting lost. In studying exhibits we detected a number of principles that indicate how to provide this property in an information space.

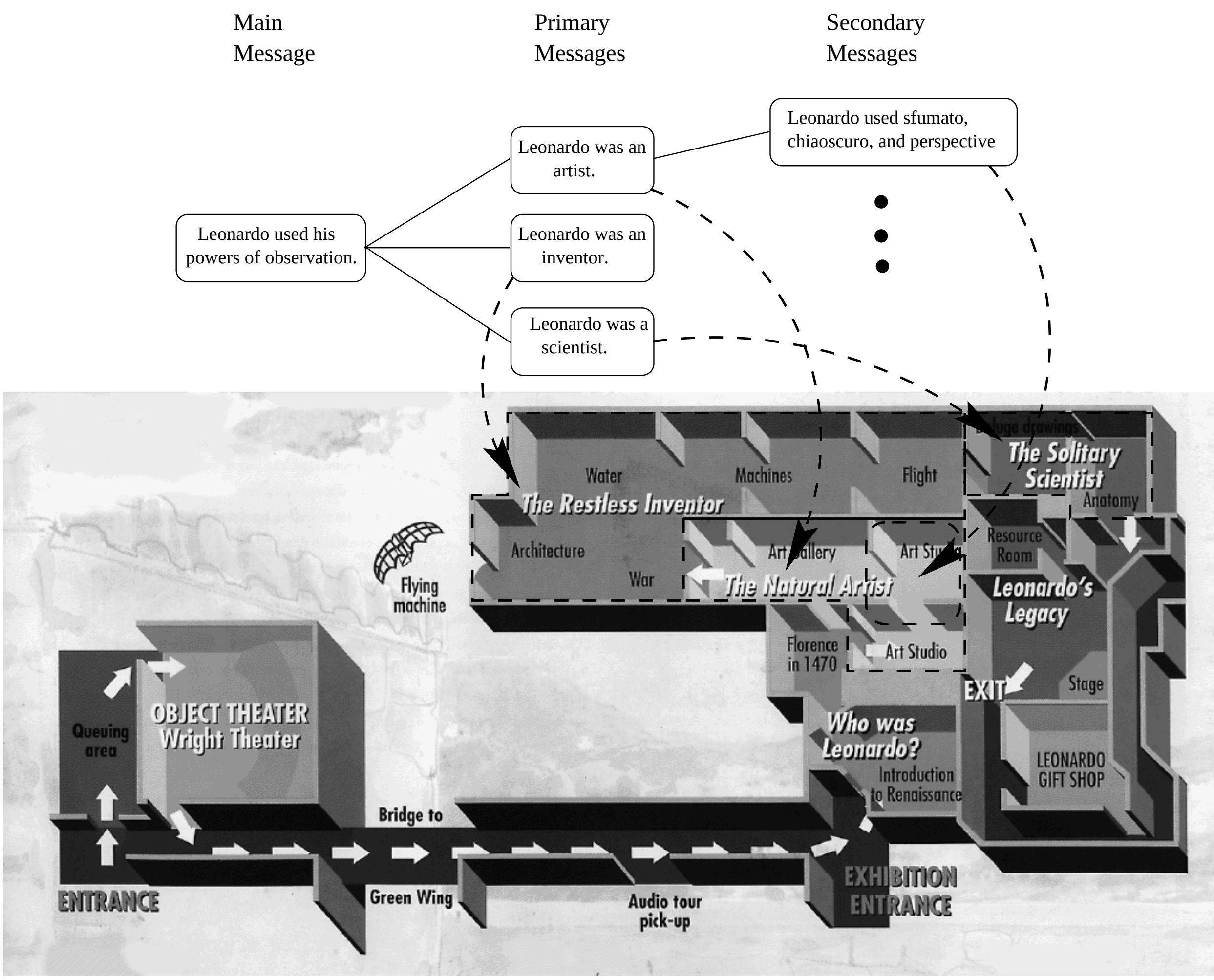

Figure 2. Principle 1: The message hierarchy of the Leonardo exhibit, and where each message was communicated in the exhibit.

Principle 6. Create an identity at each location, different from all others. Give every location a unique perceptual identity, so that the navigator can associate the immediate surroundings with a location in space. This speaks most directly to the first criterion for navigability, the ability to recover position and orientation.

This principle indicates that every place should function, to some extent, as a landmark -- a recognizable point of reference in the larger space. This principle is discussed in (Lynch 1960).

Principle 7. Use landmarks to provide orientation cues and memorable locations. Landmarks serve two useful purposes: as orientation cues and as memorable locations. If a navigator observes a landmark from the present location, the navigator can deduce his orientation in relation to the landmark. A desirable property of a landmark for this use is visibility, the ability to be seen from a large surrounding area.

Lynch noted the use of landmarks as especially memorable locations: in his sketch-map interviews, he found that different respondents marked or mentioned many of the same places. It is these memorable places that can provide instant recognition of one's location. Lynch cites Boston's gold-domed State House as an exemplary landmark for its unique appearance, spatial prominence, and symbolic importance. Landmarks associated with decision points, where the navigator must choose which path of many to follow, are especially useful as they make the location and the associated decision more memorable. Landmarks are also used in the National Museum of Natural History (as for example, a tower near the entrance to the fossils exhibit, which has several paths leading away from it).

Principle 8. Create well-structured paths. Well-structured paths are continuous, have a clear beginning, middle, and end, confirm progress and distance to their destination along their length, and have a directionality or "sidedness" that allows a navigator to easily infer which direction he is moving along. A well-structured path maintains a navigator's orientation with respect to both the next landmark along the path and the distance to the eventual destination.

Some city streets have some of these properties: building numbers change monotonically, providing directionality; the change in numbers provides a sense of progress and distance; additional cues come if building numbers change systematically with each block; and the entire street has a beginning and end. We are often not very aware of the utility of these properties until they are missing, which is one of the reasons why navigation is more difficult in Boston (where numbers and blocks are not correlated) and Tokyo (where building numbers are assigned chronologically, not spatially; note that this severs the connection between a navigational affordance – an address – and the semantics of the domain – location).

Principle 9. Create regions of differing visual character. Subdivide the space into regions with a distinct set of visual attributes. The character that sets a region apart can be some aspect of its visual appearance, a distinction in function or use, or some attribute of its content that is consistently maintained within the region but not outside it. As an example, the John F. Kennedy Museum exhibits are divided into regions relating to his early campaigns, his Presidency, and his family; visual aspects of the exhibit suggest the different regions (e.g., moving from a reproduction of "Main Street USA" to rooms suggesting White House decor). Regions may not have sharply defined boundaries, or their extent may be in some part subjective; but a minimal requirement is that there is a generally agreed space said to be within the region, and a surrounding area said to be outside it. This principle is also discussed in Lynch.

Principle 10. Use survey views (give navigators a vista or map). When navigating in any type of space, a map is a valuable navigation aid. It places the entire space within the navigator's view, and allows several kinds of judgements to be made readily:

- the location of the navigator, and what is in the immediate vicinity;
- what destinations are available, and what routes will take the navigator there; and
- the size of the space, and how far the navigator is along his chosen path.

In addition, the survey view provides a ready image of the space, which can provide the basis for the navigator's mental map. Many of the exhibits studied had a plan map of the exhibit space, provided either as a wall-mounted display or on a brochure given to visitors upon entry.

Principle 11. Provide signs at decision points to help wayfinding decisions. A sign embeds additional information into the space to direct the navigator's next choice. The information should be relevant to both the choices offered to the navigator at that point, and the larger goal of the navigational task. Simply put, a sign should tell the navigator what's in the direction it points, and the destinations so indicated should help the navigator reach the eventual goal. This principle is described in (Arthur and Passini 1992) and is familiar to anyone who has hiked a trail with good signs.

Principle 12. Use sight lines to show what's ahead. Give the navigator a more extensive view in a particular direction, and a goal to draw him in that direction. In an exhibit space, in which the first-time visitor has uncertain expectations as to its extent and purpose, sight lines are valuable means of giving enough information about what's ahead to encourage the visitor to move farther. Based on that sample, the viewer can determine if that direction is of interest or not.

To make a sight line interesting, the designer can provide a "wienie"[3] -- a goal to navigate toward (Figure 4). It might be some feature or object that is striking or unusual, something to spark the navigator's interest. It is the reward

[3] The term comes from Walt Disney, who insisted on their use throughout his amusement parks (McLean 1993).

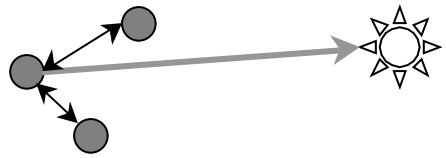

Figure 3. Principle 12: The sight line (shaded arrow) to a "wienie" gives the navigator a destination to move toward.

for choosing the path that it lies at the end of. This principle is discussed in (McLean 1993).

Course VI: A Navigable Information Space

As a design exercise applying these principles, an information space was created for the Electrical Engineering and Computer Science subject listings at the authors' institution. The Department offers about 180 subjects each term for undergraduates and graduates, distributed among seven concentration areas. The space contains catalog listings for each subject, as well as hyperlinks to additional on-line documents describing degree requirements, academic advising, and examples of theses in each concentration.

The space was designed for those who were interested in browsing the subject listings for the department. They may be potential students completely unfamiliar with the catalog, undergraduates who have taken some prerequisites, or graduate students who are interested in advanced coursework.

The Organizing Principles

The organizing principle was chosen to allow each of these potential users to locate a point in their academic career and browse information about the available choices at that point. It applied Principle 2 (*use a constantly evolving attribute to sequence material*) to construct a (roughly) chronological path through the subject listings, corresponding to the educational choices faced by students in the department. After choosing to pursue a degree in EECS as a graduate or undergraduate, a student then picks a departmental concentration in which most elective coursework is taken. The student may also take subjects not listed with a particular concentration (grouped into "Other Topics"). Before graduating, the student completes a thesis and then seeks employment opportunities or internships.

Navigation Features

Once the chronological organizing principle was set, navigability features were added to the space. Each of the major phases of a student's career became a *region* (Principle 9) containing links to relevant resources. The regions were connected by *a well-structured path* (Principle 8) beginning at the "Welcome" region and ending at the "After Graduation" region.

The header subjects deserved special significance as *landmarks* (Principle 7) in the space for two reasons. First, as "entry points" for further work in a departmental concentration they are uniquely identified with that concentration and its region. Second, they stand at the decision point where a student chooses a concentration to pursue.

Presentation

Figure 5 shows one possible presentation of this design, implemented as an HTML imagemap. Each node on the map is linked to a subject listing (black circle) or document (white circle). To allow users to both skim the space and dive in for more detail (Principle 5), the titles of regions or subject groupings are linked to lists describing the contents of the region or group. The main regions for subject concentrations are gradually shaded, giving the paths through them a directionality or sidedness. In the survey view, the user viewpoint is a static bird's-eye view of all the available resources; the user does not explicitly navigate by changing that viewpoint, and every resource is one click away. Instead, the navigation features serve to organize the visual presentation of the map.

An alternative presentation was developed as an immersive, exhibit-like 3D space in which the user could manipulate a first-person viewpoint. The layout and placement of navigation features in the space corresponds to those in the information map; however, the dynamic viewpoint requires additional navigation aids to be employed. For example, signs were placed in the space at decision points (Principle 11). The main sight line in the space down each corridor begins with the header-subject landmark (green sphere) and ends with the goal of a thesis-example wienie (red cylinder). Those corridors are gradually shaded to indicate progress toward the wienie. The space was implemented in VRML and also includes a "you-are-here" map that is dynamically updated with the user's position and orientation (Principle 10) (Figure 5).

Related Work

Designing knowledge access systems for user navigability is a continuing research concern. Furnas characterizes navigation through an information access interface by the metrics of Efficient View Traversibility (EVT) and Effective View Navigability (EVN) (Furnas 1997). In a space that is view-traversible, a desired resource is always small number of moves away, while in a view-navigable space a resource far away has sufficient local visibility to allow the user to move toward it. Several of these principles intend to improve the traversibility and navigability of information spaces.

Other researchers have focused on how user navigation through an information space can inform the development of spatial mental models (or cognitive maps) of the space. Chalmers et al. augment an existing document visualization with imageability features to assist the development of a mental map of the space (Chalmers, Ingram and Franger 1996). Chalmers also discusses the need for a strong correspondence between spatial presentation and content semantics (Chalmers 1995). Lokuge et al. use the trajectory mapping technique (Richards and Koenderink 1994) to construct a path through tourist attractions that reflects how subjects conceptually associate the attractions with each other (Lokuge, Gilbert and Richards 1996).

Other work has aimed to create spatial views of knowledge collections. An early example is the SemNet system (Fairchild et al. 1988). More recent work includes Rennison's Galaxy of News system, which visualizes UseNet articles in three dimensions (Rennison 1994), and Carrière's *fsviz*, which visualizes large information hierarchies (Carrière and Kazman 1995). (For recent surveys of information visualization, see (Card 1996) and (Young 1996).) Although survey views are by themselves a valuable aid to knowledge tasks, they can become even more effective when designed around navigability features.

Conclusion and Future Work

In this paper, we have articulated a small collection of design principles that indicate how to organize and present navigable information spaces. Key to the use of these principles is that navigation features cannot be assigned arbitrarily, but must be matched to semantically significant features of the task or the domain. For the design presented here, a path through the EECS subject listings was a student's educational career; a potential user could locate an appropriate point along that path and begin to browse the available material.

These principles are intended to guide the conceptualization and interface design of information spaces such as Web sites and bibliography collections. The tutorial purpose of educational exhibits suggests these principles apply most readily to information spaces that describe an entire body of knowledge to the user. Future work will help us to determine whether they are also effective in other information space tasks, such as the familiar search and retrieval of individual chunks of information (e.g., an article, single web page, etc.). We are looking to augment our collection of design principles to address other such tasks, including search, comparison, and sensemaking. The practice of other real-world information architects such as librarians will be a source of valuable design knowledge in this pursuit.

Ongoing research will develop a design tool that can take a description of the knowledge domain of an information space, recommend design moves based on these principles, and produce a prototype visualization of the space. This will permit exploration of the problem space posed by design for knowledge navigation, and evaluation of the principles' effectiveness.

Acknowledgments

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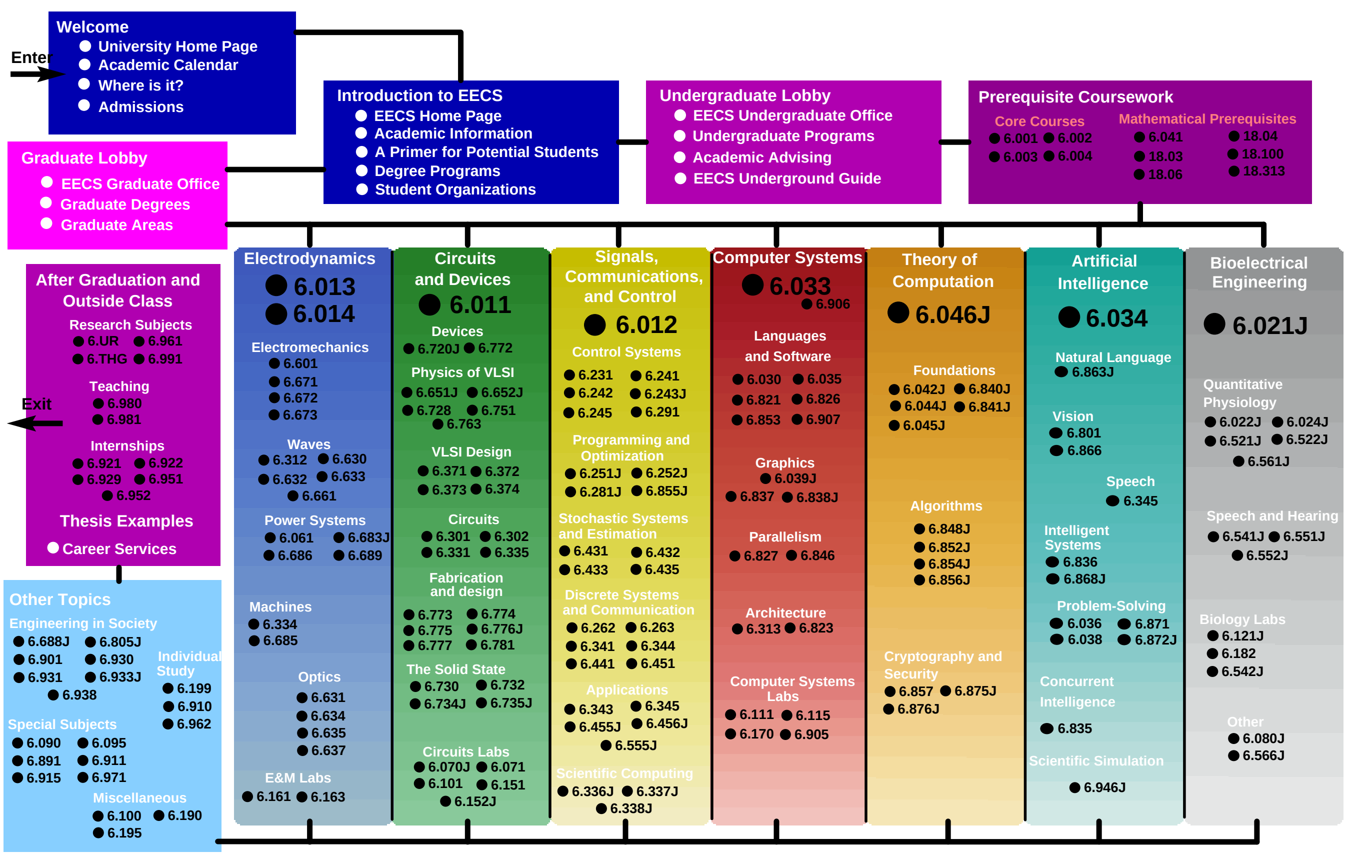
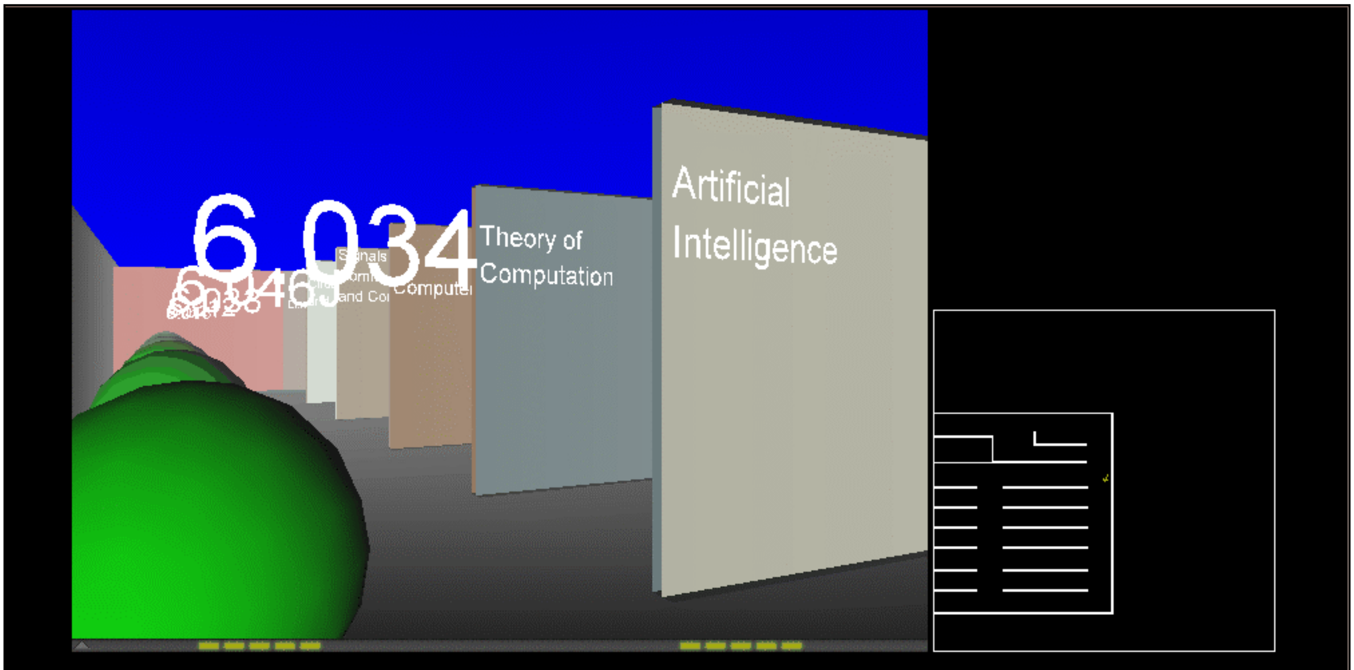


Figure 4. The information map of EECS subject listings.



6.034 Artificial Intelligence

Prereq.: 6.001
Units: 4-4-4
Lecture: *MW9* (10-250) **Recitation**: *TR10* (34-302) or *TR11* (34-302) or *TR2* (34-303) or *TR1* (34-303) or *TR12* (34-301) or *TR3* (34-303) or *TR11* (36-156) or *TR12* (34-302) or *TR10* (34-303) or *TR1* (24-407) +*final*

Introduces representations, techniques, and architectures used to build applied systems and to account for intelligence from a computational point of view. Applications of rule chaining, heuristic search, constraint propogation, constrained search, inheritance, and other problem-solving paradigms. Applications of identification trees, neural nets, genetic algorithms, and other learning paradigms. Speculations on the contributions of human vision and language systems to human intelligence. Enrollment may be limited.

Figure 5. The immersive space of EECS subject listings, with a view down the hallway of header subjects. Each entrance off of that hallway leads to a corridor of subject listings for that header's concentration. The "you-are-here" map is on the right of the screen.