“Through Plane”: A Kinetic Model for Information Retrieval

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Abstract

The proliferation of information available in data systems presents problems in load handling and efficient feedback from the information system to the user. Search inquiry systems are generally text based and problematic in relation to the user’s interaction with them.

This paper proposes a theoretical three – dimensional visualization model incorporating kinetics as an alternative to text- based data retrieval systems. The paper outlines the basis for the modeling applied to the visualization of an information retrieval system and examines the mapping of kinetic structures to the model as correlation’s for search queries. Further directions for the research are considered in the conclusion.

Keywords

Information retrieval: information search and retrieval: image systems: 3D information visualization and visualization design.

INTRODUCTION

The prevailing paradigm employed for conceptual modeling in information systems is based on semantics, written language. Text based retrieval systems are the most commonly used as the means for search procedures for information systems. The ‘semantic perspective’ of organizing information in this manner is essentially two-dimensional and can be highly abstract. As the search procedure can be relatively opaque and non-interactive the user can be left with little or no navigational directives as to the placement of the search query relative to the domain.

The growth of the World Wide Web (WWW) has made a vast amount of information available to individuals. In the case of Internet and WWW the language used is predominantly English. English is highly abstract and is low on contextual information. When browsing information systems, retrieval systems based upon key word query engines are problematic and limited particularly when the size of the database becomes extensive. Knowledge about the semantics of the information retrieval system is fundamental for successful search request formulation.

As the area of culture, communication and technology widens, so it starts to become apparent that the increase of electronic, networked, and ephemeral information is raising issues regarding the development of new tools and cognitive models to process this information (Ess and Sudweeks, 1998). With the advent of virtual reality it becomes an option to consider three-dimensional representations and entire virtual environments to visualize data contents

VISUALIZATION

As data systems become more extensive, information visualization by taking advantage of processing speed and graphical capabilities of computers enables users to interpret large amounts of information. Visualization of data makes interaction with a database of documents more graphically orientated with the main objective to make it easier for people to use and understand large amounts of data and increase the speed of searches for data.

Visualization provides opportunities for interaction with the data base material itself without a detailed knowledge of the search query language. This in turn relieves the user to some extent of the cognitive load involved in using text based query systems as the visualization of complex data lends itself to the mapping of relations between documents. In this way some of the cognitive load could be taken on by the representation of the domain.

There is research to suggest that displaying data in three dimensions instead of two make it easier for users to understand (e.g. Ware and Franck, 1994). Visualization of data can be used to emphasize patterns of thematic connection or similarity between documents as well as supplying navigational information to the user as to the position of any query within the domain. "Bead" (Chalmers, 1994) a prototype system, uses three-dimensional visualization of data to emphasize patterns. It suggests that what must be seen are the relationships between data if the user is to enter successful search queries into any retrieval system without knowledge, or a limited understanding, of the appropriate search query language.

Another direction visualization of data indicates is the mapping of the physical world onto computers. Information visualization inherently uses people's perceptual abilities to understand information and implements physical characteristics in the virtual environment through computer graphics. Use of zoom tool is one example of such mapping (Robertson, Mackinlay, and Card 1991) and Bead makes use of spatial distance to correspond to thematic similarity. This allows people to move from cognitive problem solving to more natural sensorimotor strategies. Such an amalgamation of the physical and virtual indicates possible different cognitive models for visualization of data.

A KINETIC MODEL

One possible model could be a kinetic one. The human body embodies certain psychological and kinesthetic qualities that are pervasive and common to most people. Many people structure their thinking through grammatical syntax derived from written language, yet there is a level of communication consistently applicable to people across different cultures which pertains to the understanding of a kinetics of movement. The theoretical model described in this paper takes a kinetic metaphor as the basis for the design visualization of the model.

Kinetics indicates relations, between the objects (bodies) themselves and motion, as well as relations to other objects and the spatial frame of reference in which the motion. The need to assign meaning not only to individual dimensions, but also to the perceptual relations among these dimensions, is an important aspect of three-dimensional display. As we are used to a space of three dimensions where it is possible to perceive individual characteristics of objects as well as their interrelationships. (Chalmers 1994) it becomes viable to map these physical parameters from a physical space to a virtual one.

A dynamic system of representation models connections between terms and the visualization of these relations by some aspect of the presentation and or interface design. Dynamic representations lend themselves to application of a history of actions and are useful in indicating navigation paths as they visualize the change of representation in time. Such representations also allow for a splitting up of complexity in time, which shields the user from the technicalities of the query engine as noted by Kurmann (1999).

The model proposed here address these aspects of visualization. It is an kinetic model for the visualization of three dimensional data exploring the mapping of kinetic structures as a basis for the information visualization design. The information visualization design is the conceptual development of how a graphical image visualizes the information. It contains the visual elements the image will consist of, how these visual elements are mapped to the underlying data, and what are the relations between visual terms (Wiss, Carr, and Jonson 1998). This paper outlines the methodology and conceptual design for the information visualization design. It proposes why a kinetic model may have value and indicates examples of users who may benefit from the use of such a model. The conclusion indicates further directions for research.

METHODOLOGY

Analysis of Kinetics

The study of bodies in motion can be linked to more formalized relationships. Kinetics can be organized in patterns of movement applying some “rules” that arrange movement into (rhythmical) motion and procedural steps. Kinetics is contextual, non-verbal (for the most part) and spatial. It includes different levels of movement, spatial location and relationships to geometry and to the ‘texture” of movements.

Kinetics encompasses common characteristics across different forms which could be “mapped” to the representation of a three – dimensional information system.

The expression of kinetics can be seen in the terms of:

- The object- the whole or the specific parts that move.
- Space- the specific direction, level, distance or degree of motion of an object relative to the volume of space it occupies. Kinetics incorporates six basic directions, forward, back, left, right, up, and down. Turn is added as a relation caused by motion on an object. (I.e. increments of a 360 degree turn: a quarter turn, half turn, three quarter turn, and full turn of 360 degrees.).
- Time- the duration of the actual movement.
- Dynamics- the quality or texture of the movement- heavy, elastic, or accented.

Presenting these four characteristics, as information to a user is basic to the modeling of the three-dimensional visualization for the domain for the kinetic model proposed. The model sought to establish relations between these characteristics of kinetics for the basis of the visual design. Since data queries have their relations to other data sets it is an objective of the model to explore possible ways of representing such connections. At this stage not all of the design patterns from the interrelationships of these characteristics are supported in the model. Movement structures have to be isolated and connections found between the objects, the space represented, the movement paths as visualized over time, and the constructs these characteristics conveys.

THE MODEL

The Kinetic Model

The focus is on the use of motion information and the interpreted analysis of kinetic content to provide the basis for metaphoric development. This is mainly indicated in the representation of the search procedure, which is dynamic and occurring in real time indicating navigational paths for the user

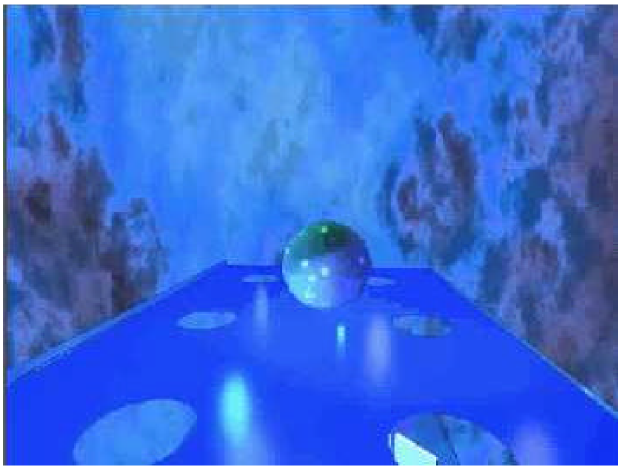


Figure 1: Dynamic representation of search query

As the search query takes place, displaying changes over time, navigation is enhanced. The user can “mark” the progress of the search procedure as it passes through the model providing feedback as to the position of their query in relation to the information system. This helps the user “learn’ from the mapping of the search query onto the model, becoming familiar with the document structure as the visualization of the search procedure progresses. The search query becomes a “guide” for the user the model visualizing the path of the query in relation to the dimensions of the domain.

An analysis of the visualization of the model follows. These relations form a general template, which can be modified and re-arranged representing the relations of different information systems.

The Components of the Model

Initially a set of representational terms had to be modeled that indicated relations between parts. These required modeling the magnitude of the appropriate domain that the search engine is browsing, representing a class of objects which indicated the processing of the search engine query, and modeling the visual display of the path of the query relative to the representation of the information system.

Kinetics, as noted, has four basic components. Applied to the model as the basis for the cognitive modeling the metaphoric mapping can be visualized by the following relationships.

The object- the whole or the specific parts that move. In the model this is visualized as a ball that is representative of the search query. The ball moves as a whole.

Space. There are two aspects here, which the model explores. The presentation space is representative of the domain providing spatial environmental cues as to the size of the domain. The specific direction, level, distance or degree of motion of an object relative to the volume of space it occupies is represented by the size of the search query, as visualized by the ball object within the dimensions of the model. Turn is added as a relation caused by motion on an object. In the model it is suggested that this relation could be indicated both from the point of origin of the moving body, and from the global origin as different tasks for navigational outcomes.

Time. Visualization of the progress of the search query occurring in real time is represented by the ball's passage through the model and its characteristic movement path on any one plane as it locates the document(s) linked to the query.

Dynamics. These function as modifiers to the actions of the ball. Adding such modifiers can represent another level of information about the interconnections within the domain. Dynamics address how the action is done, the degree of change, or the manner of change. Examples would be spatial modification (position, path), and physical modification (initiation of movement, resultant movement).

The kinetic model, at present, explores a hierarchical model for visualization of data. This is indicated in the representation by the distribution of the pattern of the planes in the presentation space and the inner pattern on each plane of the nodes represented by the holes. The model "maps" a traditional "tree' by the arrangement of the planes in a vertical sequence from the top of the presentation space to the bottom and the distribution of the nodes (holes) on each plane. The amount of cognitive information is related to interaction between the components on the screen at any one time.

The Query

Text queries initiate the search procedure. Queries are mapped into the model via the ball representation. Each ball as it enters the virtual environment represents a search. The radius of the ball is modeled to represent the value of the word(s) weighted to the query. Each ball enters the visual representation and proceeds to move through the planes until it reaches the appropriate plane as mapped via matching the radius of the ball to the radius of the holes on any one plane. The query, as represented via its movement path, then proceeds to map the relations between nodes on any plane by the movement path followed on the plane.

This is helpful in providing feedback to the user as to the structure and size of the domain, to the level within the domain that the search query has proceeded to, and to the weight of the search query in relation to the "home" plane. Accordingly the three- dimensional representation provides visual feedback aiding domain knowledge

The Movement of the Search Query through the Model

The movement paths are representative of the passage of the search query in the domain. They are modeling the relations between, the search query and the application domain, the depth of the search query in relation to the total depth of the model, and the relations between a plane and the nodes represented by the holes on the plane.

This mapping of the paths in the representation to indicate an underlying kinetics was based on broad movement principals. The structure of movement conveys the large general statement of an action first followed by increasingly specific ones. Movement often needs to be stated in general terms first to convey the action or activity. "Something happens', something occurs: the occurrence of movement of some kind. Moving from the general description to a more specific one requires more information related to further amplification of the motif description indicated in the movement. This understanding of movement was linked in the model to the "dimensions" of the search query. The larger the query the broader and simpler the movement as described in the model as the path of the ball. Each movement of any ball within the frame of the model presents mappings of domain parameters to the movement syntax.

Application of movement patterns and dynamics to represent the relations between data sets on any one plane, and the passage of any search query through the model requires analysis at a further stage of research involving navigational and interface design issues.

Considerations need to be to address the choice of movement description and the indication of the movement design in space. The addition of modifiers suggests ways of taking into account user profile and task application. Emphasis would have to be on cognitive aspects. Changes in speed, and changes in quality of movement could be implemented as indicators of hyperlink structures in the domain. Such an approach lends itself to evaluating user tasks that the model could support as outlined by Sineriderman (1996). For example an elastic movement could indicate a dynamic link, a heavy accentuated movement could represent a hard-wired link. The analysis would have to be carefully evaluated as to the "readability" of the metaphor in the visualization.

The Domain Structure

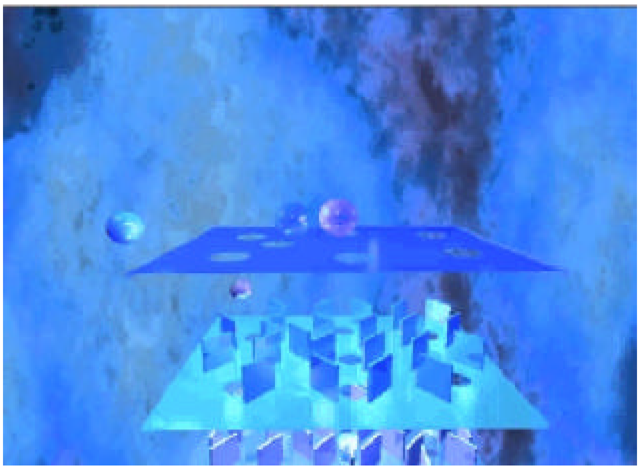


Figure 2: Three – dimensional data visualization showing sequential planes

The model's architecture indicates the level of information attached to the search query and the organization of data within the domain

In this particular representation the visual model was structured in the following manner. A set number of planes appearing as consecutive slices of a cubic volume of space. The planes are representative of the various layers of information contained within any one domain. Each plane has a certain number of holes, which act as "gates" to the next plane underneath. The holes diminish in size from each succeeding plane, the largest holes being on the uppermost plane the smallest are represented on the lowest plane of the model. The decreasing size of the holes represents the information weight calculated for each node. Movement of the search query is diminished as the ball progresses downward on the model. This is achieved by the construction of architectural 'walls "on the lower planes. The construction is a template and could be altered to reflect different parameters for other three – dimensional models discussed later in 'Further Directions'.

Although still theoretical it is hypothesized that within each plane, arrangements of nodes are mapped as relations representative of similarities in word usage. Individual documents take their places in these patterns as a result of the words used within them The core nodes are placed in the innermost areas of the planes, while the nodes with the lesser word weights are moving towards the edges of each plane. In this manner the visual representation maps for the user document relations within the data for the domain. This application of spatial proximity to express similarity in some more abstract interpretative framework has been successfully implemented in other three-dimensional information systems, notably Bead. (Chalmers, 1994). Similarly to Bead, the kinetic model allocates to any document two functions. It must act as an autonomous unit and it must also express a relationship to a higher level structure.

Rules

To provide consistent navigation and user models certain rules had to be placed into the three-dimensional visualization. These rules addressed relations between the paths of the balls, and between the search query and the radius of the balls. The “rules” formalized the syntax for the display of movement in the model at any time and would need to be indicated in the navigation model.

The following relations were placed into the model.

Movement Pattern of the Ball	Ball
- A ball entering the model	- Represents a search query initiated
- A ball between layers	- Is still in a search procedure.
- A ball turning on any one layer (turn is added as a relation caused by motion on an object. Turn is mapped as increments of a 360 degrees: a quarter turn, half turn, three quarter turn, and full turn of 360 degrees, either to the left or right).	- Is still in search procedure
- A ball that leaves the model completely	- Represents an unsuccessful search query.
- A ball falling through a hole	- Represents that the search query is of a lower level of information than the layer the ball is leaving.
- A ball falling into a hole which has the same diameter and stays there	- Represents a successful search query
- A ball that is not visible in the presentation space after a search query. (This rule therefore defines the presentation space as representative of the domain.)	- Represents that the search query is beyond the scope of the domain.

These are the simplest levels of rules to convey the representation to the user and indicate navigational paths, which are transparent. This process could be extended depending upon the size of the domain chosen. Additional ‘rules” could be include the actual movement patterns themselves at any time on any plane. What for instance is the syntax conveyed by a ball turning (increments of 360 degrees resulting in changes of direction on the spot to the position of the ball), jumping (sudden change of level defined as always upwards in this model? Or by sliding (loss of momentum over distance involving continuous contact with the ground plane)? Can the dynamic behavior of objects offer possibilities for further modeling related to attributes of data: level of importance, relations to previous data, linguistic modeling as in links to associated words? This could be a possible extension of the model but is outside the scope of this paper.

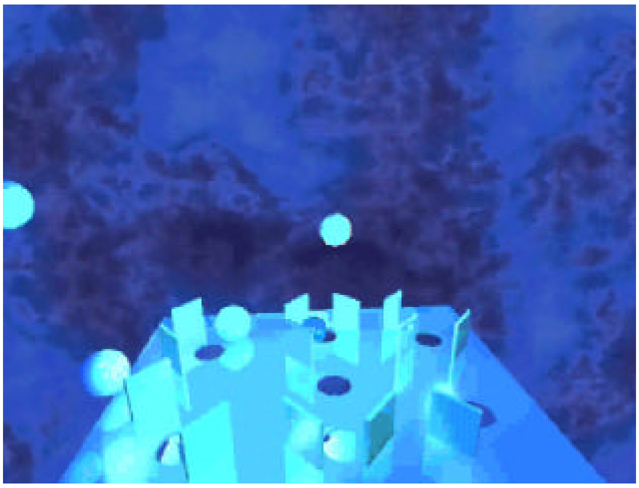
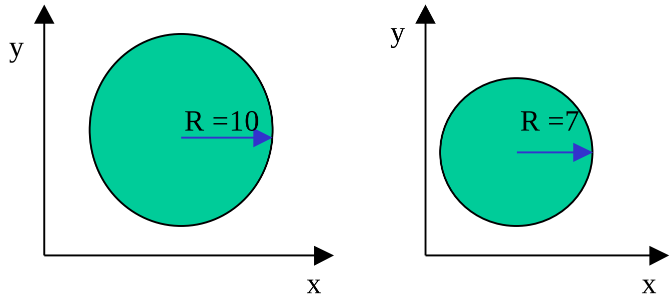


Figure 3: Successful search query represented by ball locating appropriate hole.

Rules for the Radius of the Balls.

To indicate the relation between the search query and the resultant visualization the question needs to be asked, what is the meaning of the radius of the ball? How does the radius reference the search query, if for instance there is a combination of two or more words?

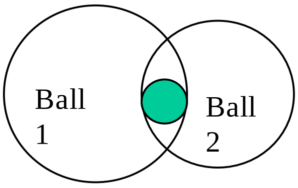


Ball1 representative of the text query"information"

r =10

Ball2 representative of the text query" systems "

r =7



Ball 1 + Ball2 for the query "information systems. The new radius which represents the magnitude of the search query is calculated by establishing the diameter of the area of intersection where ;

$$r = \frac{d}{2}$$

Figure 4: One explanation of the relation between the radius of the ball and the information load.

Figure 4 represents one possible understanding of the relation between the varying radius of the search object and the text query. A simple text query where ball 1 (Bs) represents the first search query, the word “information” This results in too many retrieved documents so the search has to be narrowed. The word ‘systems’ is added represented as ball 2 (Bi)

When the two words are linked in a search query the resultant radius for the text query ”information systems” is the radius of the area defined by the intersection of ball1 and ball 2. Then if there is a combination of two words or more the following equation becomes a rule.

?? Bs Bi ?? = rs + ri

The representation of the model would impose limits to the least dimension that the radii could be represented as within the model. In this manner the “holes” on each plane through which the information is being “sieved” can be calculated.

Modeling the co-ordinates of the search procedure

The representation of the search query in its final position in the model indicates a relation between the information weight of the query and the co-ordinates of the position of the ball in the model.

WHY A KINETIC MODEL

Although the research for the kinetic model is in early stages certain aspects deserve comment.

The model represents a dynamic visualization of data where the path of the search query is represented in real time as part of the search procedure. The movement of the query represents conceptual data as to the layout and relations between data in any one domain. The representation of the path of the search query ascertains the relations between data, processing two functions simultaneously. Firstly it allows the user to retrieve information, to find a specific document within the information resource, and secondly by the visualization of motion paths represents to the user the results of “browsing” . This could overcome problems concerning cognitive overhead and disorientation (“the feeling of being lost in hyperspace’) (Conklin, 1987). Cognitive overhead has been an issue looked at by other visualization systems (e.g. Footsteps, (Nicol, et al.1995), yet the distinction here is that the search query and the cognitive map of the domain are synonymous. The user can view and navigate through the environment simultaneously. As has been noted, (Lynch, 1995) simple strategies can be used to search the entire hypertext space, such as to ‘reach home’, always go up. It might also be as the Kinetic model suggests, that physical structures offer users an intuitive understanding of the real world that may be easier to navigate by. and lessen the cognitive load for the user (Tennison and Churchill.1996)

Visualization of data only functions effectively when the user can intuitively understand the meaning of the objects and their relationship in space. Otherwise any visualization of data is of limited use. (Demaine, 1996). What is suggested in this model is a possible application of a different cognitive model for information systems. It allows the user an intuitive understanding of the relations in the domain by the application of movement principals as the basis for the metaphor.

Possible Applications for the Model

What the kinetic model offers over other dynamic models? A different cognitive model for the possible visualization of data that could be beneficial for certain groups of people. It is suggested that this model could have immediate applicability to domains that would be enhanced by the structures of a kinetic model. (Dance, gymnastics, physical education and such correlated areas). The following groups of people may benefit from such a model

- Children and the application to educational systems.
- People whose first language is not English or have limited understanding of English.
- People whose cultural paradigms are less conceptual and abstract than English speaking cultures and have an understanding of meaning related to a kinetics of movement.
- Groups who familiar with interactive games and are conversant with the structures linked to visualization of movement to convey relationships within the game.
- People with little or no computer knowledge, possibly for economic or social reasons.
- Medicine. Biomedical virtual environments can be dense carrying a high cognitive overhead. Rapid location of any visualized structure within the underlying physical data is often lengthy. Application of the kinetic paradigm has possibilities.

FURTHER DIRECTIONS

One possibility is to implement the usage of "search intermediaries", proposed by Wiesman (1998). Hoppenbrouwer (1998) proposes the use of search intermediaries to "both shield the user from the technical aspects of the true query engine and provides background knowledge about the document's domain". Possibly kinetic objects, in addition to the representation of the search procedure, could be utilized in this manner in the navigational model. They could act as guides. These would help the user visualize and understand the relations between searchable terms and provide navigational maps of linkages as indicated in a three dimensional representation.

The characteristics of the objects (balls and holes) representative of the search engine can display a variety of behaviors, which facilitate navigation, and feedback to the user. These could cover size, frequency of motion, dynamics of motion, color, and opacity. Such characteristics could be linked to a representation over time allowing the user to view previous paths for certain duration. These could be extended in future models indicating the possibilities of designing flexible information models based on differences in content.

The model is a template and indicates by its architecture that it could be applied to a number of different domains. The planes could be arranged in different patterns to indicate the spread of documents in various domains. The domain could be visualized as a series of horizontal planes arranged from left to right indicating a tree like arrangement, or as a series of planes structured as an aerial view without overlapping of planes. This indicates the possibility of developing different spatial models yet using the same visualization objects as in the proposed model in this paper.

Visualization of data provides information as to the success of the search procedure, the connection between the search query initiated and the layer of information the query is currently linked to. In terms of the information system and how the data in any one-information system is organized the representation sought to explore how the model could indicate the document structure. Is the information weighted in any one way? Is there a hierarchical structure inherent or is the information organized as a two – dimensional type of net both highly and loosely connected? This needs to be clarified in future research.

CONCLUSION

Ways of representing and interacting with information are being extended as three – dimensional models for data visualization indicate new structures for content production and retrieval. The outlined research in this paper is in progress. It attempts to indicate a basic template for a three-dimensional visualization of a data system organized on the principals of continuity of search procedure indicated via relational modeling. The model indicates a flexible and dynamic template for the design of information retrieval systems.

The next stage for the research is to apply the model to a particular data set within a domain, to test its viability. Such an empirical approach involves a case study, survey and experiment to produce empirically based guidelines, method, and model.

It is proposed the domain would be Medicine with the visualization model mapping the data set for cancer as it occurs in young people.

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