Geometry and Graphics for Developing a Multimodal, Multidimensional Desktop Virtual Reality Framework

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Abstract

This paper describes how geometry and graphics are employed to design and implement an intermodal multidimensional framework. Geometry and graphics can be judiciously juxtaposed within desktop virtual environments to facilitate information visualization, extraction, and analysis. This paper demonstrates a desktop VR system that exploits the potential of geometric shapes and graphics functionalities to depict a multidimensional framework for visualizing a campus map. This framework facilitates visualizing at different levels of detail (LOD) and switching among different modes of visualization. 3-D virtual models of buildings have been integrated into the framework to facilitate immersion and navigation. The intermodal denotes that various forms (modes) such as simple graphics, photo-realistic, and non-photorealistic renderings have been incorporated into the application. The entire application has been built using Web-friendly technologies such as VRML/X3-D, Java, and JavaScript to facilitate hosting the application online. Overall, the framework demonstrated in this study significantly aids information visualization and analysis. The authors believe that this notion can be extended for a wide range of applications across multiple disciplines.

Introduction

This paper describes the design and implementation of a multidimensional framework that not only serves as a platform to visualize the Purdue campus in 3-D but also serves as a "visual analytical database." The importance of graphics communication and its influence over the cognitive process when solving problems has been well recognized [1]. This is especially relevant today, when we are dealing with multiple, quite frequently incompatible data formats. For instance, an industrial project might typically involve documents, spreadsheets, design files, and audio and video files. It is quite easy to get lost while constantly alternating between these data formats and trying to correlate the relationships among such parameters.

The efficacy of visualization in unravelling real-world problems has been highlighted in many works by authors from miscellaneous fields. Several authors [2, 3] emphasize the importance and usefulness of visualized data. Visualization not only empowers the user to gain an insight into the data being analyzed, but also enables operational demonstration of the results of the methodical process [4-7]. Visualizing any information in a specific way, for instance, while talking about statistical data, bar charts and pie graphs pop up in our minds as we are used to it over time and feel more comfortable perceiving items visually. These kinds of representations have efficiently served needs of the respective communities over time, but we must not be resistant to change and be willing to adopt new methods of representation that facilitate better information extraction with optimal results. These new methods will be even handier today, considering numerous interdisciplinary applications (industrial and academic). Integrating multifarious data types in diverse format using a multidimensional framework will serve in integrating, presenting, and communicating diverse forms of information in multiple modes.

This paper uses geometry and graphics as tools to create a multidimensional framework to facilitate information extraction. The authors emphasize the potential of alternative multidimensional representations in integrating, presenting, and communicating diverse forms of information in multiple modes. Considering the visualization advantage that virtual technologies can provide, [8] stated, “Virtual reality (VR) technologies provide a unique method for enhancing user visualization of complex three-dimensional objects and environments.” The authors have used desktop virtual reality, owing to its ease of access and dissemination. Virtual reality can be defined as the application of an artificial environment generated by computer technology to simulate some targeted activity [9]. By using 3-D visual scene renderings, planners and decision makers can identify and segregate information. Along with facilitating presented information, a desktop VR-based graphic visualization also enables seeing and understanding hidden information among data sets.

A principal disadvantage with mainstream visualization platforms is that the data are provided in an inflexible manner. In other words, the person who designs the visualization framework presents the information in a manner that s/he deems appropriate. While this may be true several times, there may be times when the user may want to view the information in other ways. An exemplary framework must allow sufficient latitude to enable user interaction with the information. The user should be able to animatedly interrelate, manipulate, adjust, and re-arrange the information according to need.

This study proposes a multidimensional visualization (MDV) framework as a window to a database that can be scrutinized, and hence it can be considered as a “visual-analytical database.” In might help to consider the MDV framework as the front-end [5], and the database as the back-end, containing all the different forms of information. The essential idea here is to exploit the immense potential of geometry and graphics to integrate different data types and data formats and present them in a manner that facilitates communication to a diverse audience. Bertoline et al. [1] state, “Engineers and technologists find that sharing technical information through graphical means is becoming more important as more nontechnical people become involved in the design/manufacturing processes.” Extending this idea, we can safely say that not only in engineering and technology, but also due to the interdisciplinary nature of today's industrial and academic projects, sharing information across a broad spectrum of users with diverse skill sets has become imminent. To this end, the authors present this novel idea of using various geometries to represent scene entities and present all the datasets via a graphical means so that the "visual analytical database" can be used by diverse groups of people with different needs.

Methodology

The following are the steps involved in this prototype study:

- First, the multidimensional visual representations are developed and presented.
- The virtual objects composing this graphical interface are enabled with sensor capabilities so that they can sense user actions such as touch, hover, and drag.
- Then, the virtual models are generated. As one goal of the framework is to provide an immersive, navigable 3-D environment, virtual worlds depicting campus buildings are generated.
- Subsequently, these virtual worlds are linked to the 3-D virtual representations representing the buildings of a university campus.
- Finally, all the different data formats (Figure 1) are also anchored (linked) to the multi-dimensional representations

Multidimensional Representations

When using the same strategies year after year, we tend to get accustomed to viewing results of information analyses in a particular way. Prejudice inhibits creativity, and hence, such repeated use of similar tools and techniques greatly restrict our ability to think "outside the box." Relying on prior strategies yields results along the expected lines, which may not necessarily be optimal. Today's requirements and results are quite different from requirements and results several decades earlier. Today's interdisciplinary environment necessitates collaboration among diverse groups of people and, hence, diverse data that such groups of people are interested in. Figure 1 illustrates the specific case involving the visual analytical database of a university campus. On the right side, we see different datasets containing diverse files such as spreadsheets, CAD files, 3-D virtual models, financial data, plans, GIS data, GPS data, and so on. It is practically impossible to use conventional 3-D representations to represent all the diverse datasets. One primary advantage with representation is that the framework allows the flexibility to envision information in the manner that is most appropriate to them. A good visualization platform should be flexible enough to allow the user to dynamically interact, manipulate, modify, and re-arrange the information in accordance with their needs.

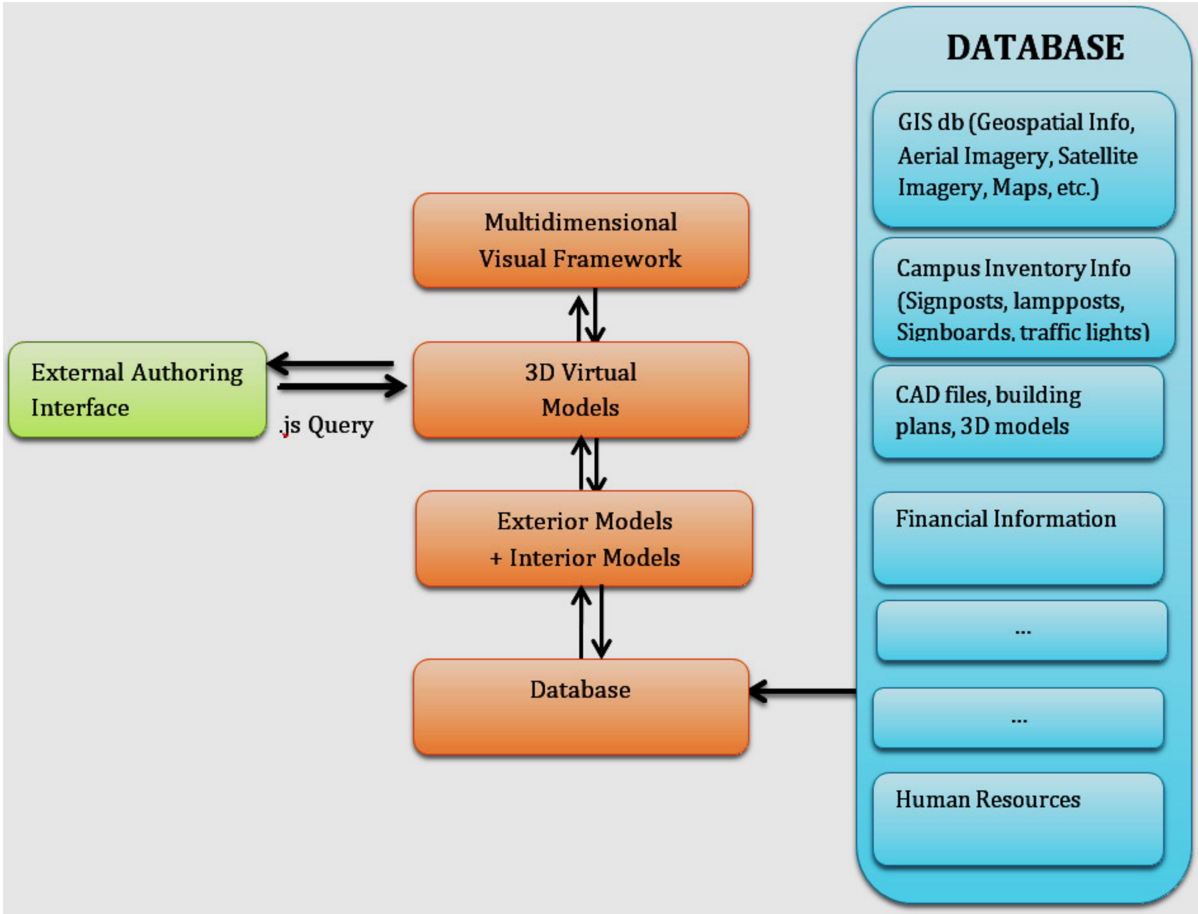

Figure 1. Framework for the prototype, “Visual Analytical Database”

The authors have narrowed down upon the multidimensional representation (Figure 2) that uses object geometries and the properties of geometric objects. This representation shows cubical and spherical objects arranged on the circumference of a sphere and a sphere at the center. Each geometric entity can be considered as a representation of a building on a university campus. Each university has a central place that serves as a hub for all university members, irrespective of their school or department. The central green cube can be considered as the administrative building in this prototype study. All the other cubes can be considered as buildings surrounding the administrative building.

Another perspective to represent can be from administrative point of view. For example, typically, universities have several schools, and each school is, in turn, composed of different departments. Figure 3 illustrates the hierarchical representation of the university’s structure. This hierarchy can be represented in the form of a multidimensional representation as illustrated in Figure 2. The green central cube can represent the university and the other yellow cubes surrounding it (with the same radius values and yellow) can represent the different schools within the university. Further ramification is represented by the smaller spheres surrounding each yellow sphere. They are color-coded differently to distinguish departments belonging to one school from those belonging to another school.

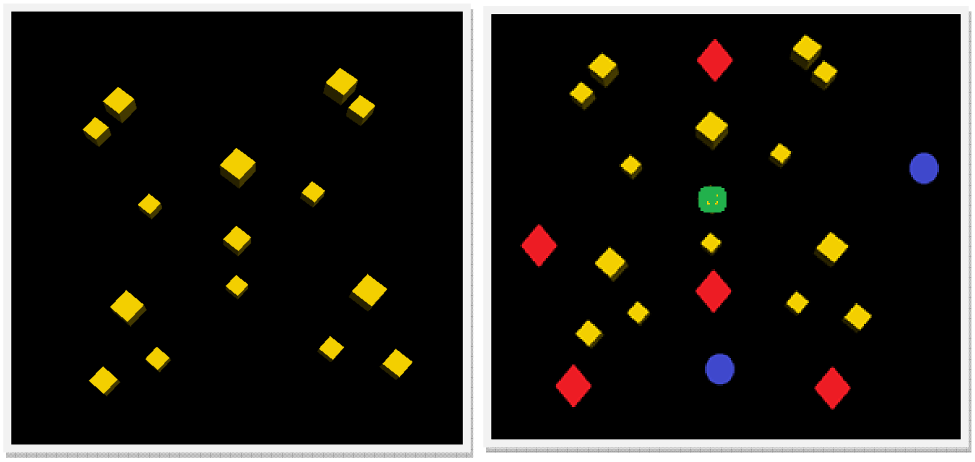

Figure 2. Multi-dimensional visual representation

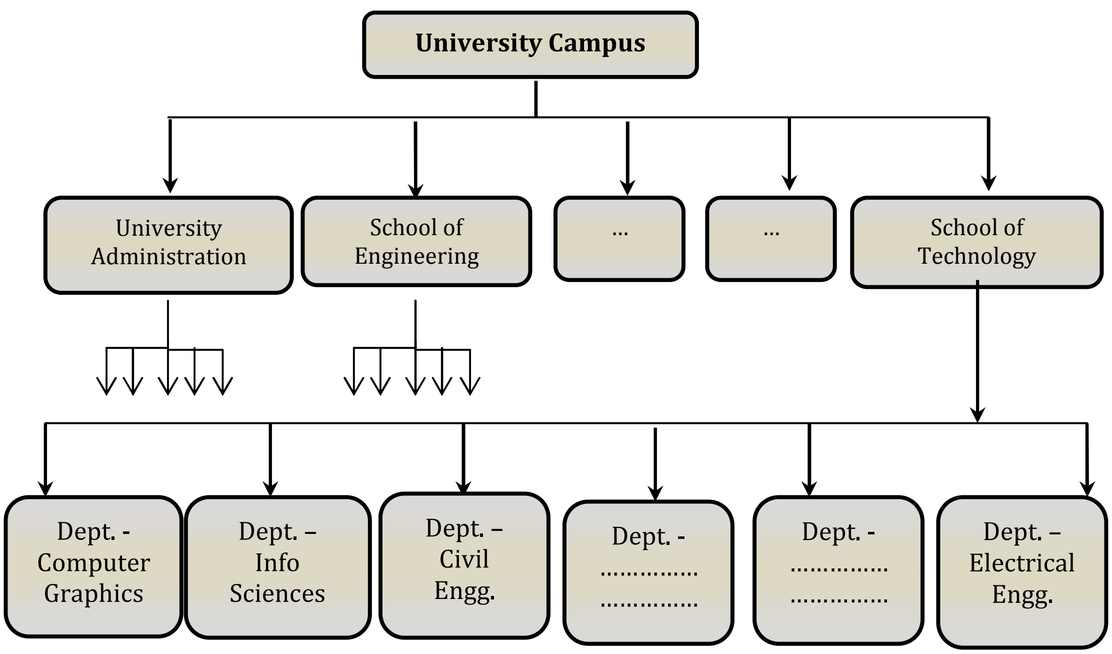

Figure 3. Hierarchical representations of campus buildings

Virtual Model

As one goal of the framework is to provide an immersive, navigable 3-D environment, virtual worlds depicting campus buildings are generated. Figure 4 below illustrates the virtual model of a campus building.

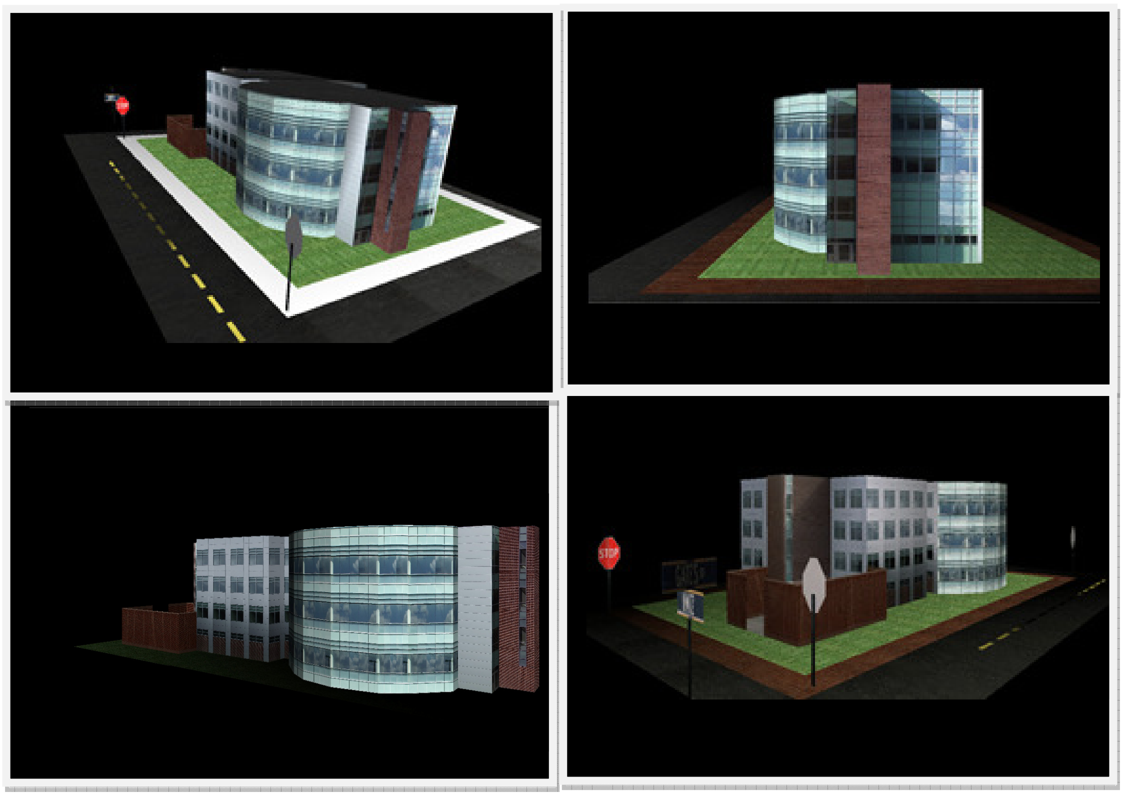

Figure 4. Virtual world models of a campus building in Discovery Park (right)

Figure 5 illustrates how these virtual models are tied to the MDVs we saw earlier. Let us consider, for instance, that "Matthews Hall" is represented by a sphere. Intuitively, this building can be grouped based on the school/department(s) that are housed in this building. However, this sphere can also have its own ramifications, as typically a single building may include several departments. Even though the purpose of this paper is not to dwell on the advantages of such virtual world representations, some important functionalities that add to the utility value of a virtual world include the ability to

- Move about in the 3-D space
- Walk through or fly over the campus
- Locate and navigate to particular points of view
- Select a particular path and display a video sequence along
- Provide different levels of detail

Virtual world objects are described as shapes with geometry and appearance. The "intelligent" objects that can sense user actions are programmed based on "Event Driven Programming," with the notion that the objects react to the user's action. Users can interact with objects in the dVR (desktop virtual reality) in several ways including selection, selection and dragging, hover, and transforming. By using the quantitative values of the dVR object properties the variables represent, various attributes can be correlated. These object properties refer to the attributes constituting the geometry and appearance of the graphic scene objects. So for a cylindrical object, attributes include values such as radius and height. Similar to the geometric attributes, attributes determining the appearance of an object also can be expressed quantitatively. Moreover, individual graphic objects can be amalgamated with the sensors to react to user-initiated events, and this can consecutively be used to deliver more comprehensive information. For example, hovering the mouse over an object displays a JavaScript memo providing a small snippet of information about the computers in that building. A thorough inspection of the shapes in the virtual scenes and appropriately written programming scripts associated with the EAI (external authoring interface) make the process of programming less burdensome. The nodes can be programmed to receive the input. Scripting unlocks up the EAI of the computer-generated worlds, thus making it possible to use Java libraries and built-in JavaScript functions. These can be controlled via eventIns and eventOuts. By channeling the values obtained from the EAI (using JavaScript/Java) through to the appropriate fields, intricate designs can be generated.

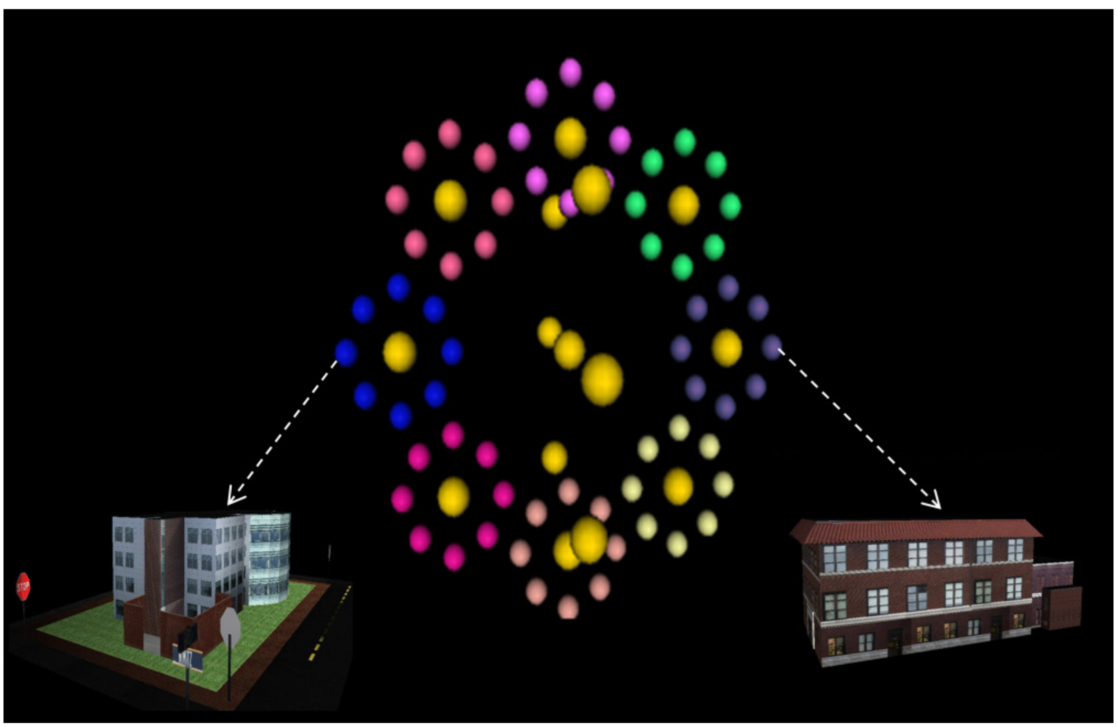

Figure 5. Virtual model tied to the MDVs

Viewing Relationships Using Geometric Objects

Correlations among database entities (virtual scene objects) can be demonstrated in a visual manner using line geometry. For instance, considering the campus example, buildings (hence schools/departments) that are part of a joint venture or an interdisciplinary project can be shown connected by using lines (Figure 5). The thin white line runs across various spherical objects representing different campus buildings. Also, various attributes can be used to differentiate between different kinds of relationships. These attributes include line thickness, line color, line style, etc. [6].

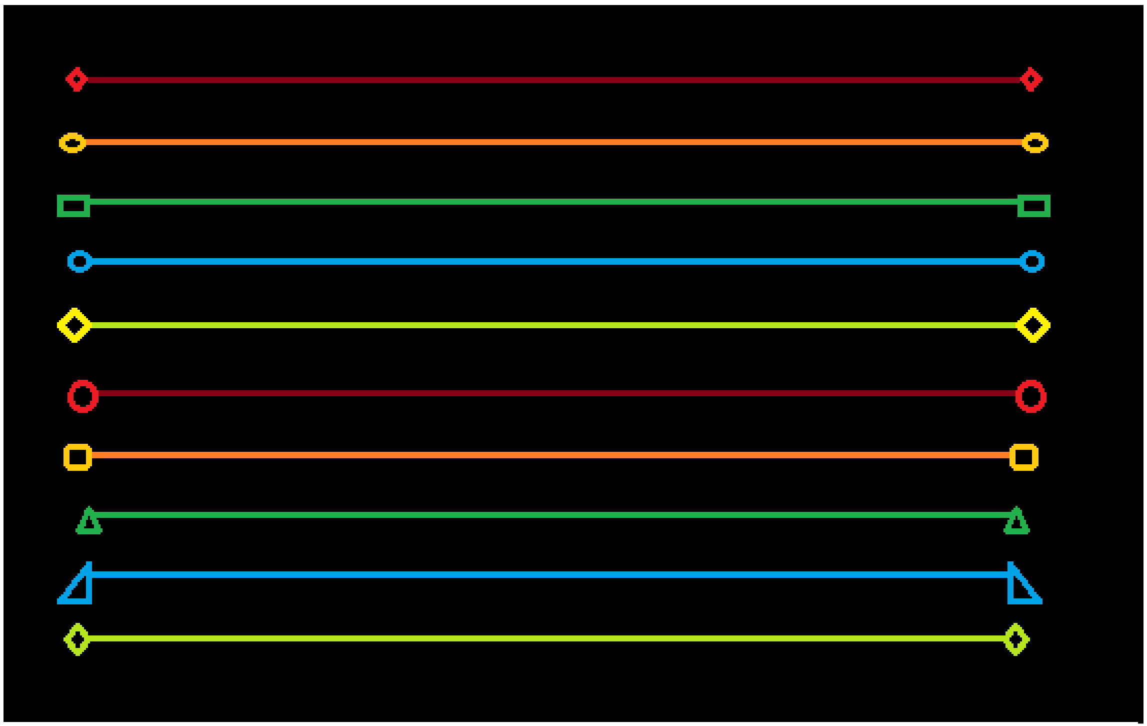

Figure 6. Line symbols to distinguish object relationships

Using this prototype framework, objects can also be grouped into clusters to illustrate objects more closely related than others that are not. For instance, if facilities are being upgraded, then the representations explained in this study can be used to indicate campus buildings undergoing maintenance and renovation.

Results and Discussion

This section discusses the cumulative utility of having a multidimensional representation. Let us consider an example of how incorporating the capabilities described in the earlier sections can be helpful in multidimensional visualization. Consider one of the two different representations for campus buildings. Both the representations have some kind of hierarchical sorting. In Figure 9a (left), the buildings are all tied to the central larger orange sphere that represents the PU, and Figure 9b on the right shows the campus buildings, using the cubes arranged along the x, y, and z axes.

Typically, most universities today have dedicated centers to manage campus IT resources. At Purdue, the ITaP (Information Technology at Purdue) is responsible for the operation and management of all computers on campus. Considering an enrollment of more than 40,000 students, this is quite a challenging task indeed. Let us imagine how the multidimensional visualization framework can come in handy in such a situation. Those buildings with 100 or more computers are shown in as red cubes. This ramification can continue to represent as many details as required, and any number of filters can be incorporated, which can be turned on or off as required. There are several buildings, especially larger ones, with open access ITaP labs. Also, there are labs in these buildings with access restricted to students of specific schools only. For instance, there are computers in Knoy Hall that are accessible only to technology majors. The size of the objects directly represents the number of computers in a building, and we can see that buildings with considerably large number of computers can be easily and quickly distinguishable. To facilitate easy recognition of buildings, each geometric object, when hovered over, shows the building name it represents. Those buildings that have ITaP labs accessible to all students on campus have their shape changed from a cube to a blue cylinder. Buildings under renovation are included within the sphere, which can be turned on or off.

For each in the above category, filters are applied. These are enabled using a sensor-enabled on/off filter (as illustrated in Figure 12). Starting with an initial representation without any filter turned on, at each level filters are turned on to identify the different categories. Furthermore, several computers on campus are the 32-bit version, while a significant number of computers use the 64-bit configuration. Clicking on the bit-configuration icon shows only the corresponding version. Furthermore, while several computers still use only a single monitor, computers using dual-monitors are on the rise. This can be identified by a dual-monitor icon added to the front face of the graphic objects.

Conclusion

The objective of this study was to design a novel structure for generating a multidimensional visualization. This study demonstrated with several examples the gains resulting from the use of multidimensional visualizations and the advantages of using them with databases. This study elucidated with instances and dVR representations the execution of an archetype application for a university campus. Such computer-generated representations simplify understanding complex relationships. This structure aids envisioning at altered levels of detail and swapping among diverse data. 3-D virtual models of buildings have been integrated into the framework to facilitate immersion and navigation. The intermodal aspect denotes that various modes, such as simple graphics, photo-realistic, and non-photorealistic renderings, have been incorporate into the application.

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Biographies

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