BUSINESS INFORMATION VISUALIZATION

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TUTORIAL

Note to Readers: This paper requires approximately 1.0 Mb in Word 97. Because it includes color graphics, a color display and printer should be used to understand its contents fully.

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ABSTRACT

With the flood of data produced by today's information systems, something must be done to allow business decision-makers to extract the information the data contains. The recent advances in visualization technologies provide the capability to begin to use human visual/spatial abilities to solve the abstract problems found in business. If business problems can be visualized with an appropriate representation, then it may be possible to use innate spatial/visual abilities to allow the business decision-maker to separate the "wheat from the chaff." This tutorial surveys the issues related to applying visualization technologies to business problem solving.

KEYWORDS: artificial reality, data visualization, decision support systems, information visualization, scientific visualization, virtual environment, virtual reality

I. INTRODUCTION

Information, once rare and cherished like caviar,
is now plentiful and taken for granted like potatoes.

The First Law of Data Smog, David Shenk, 1997

With the flood of data produced by today's information systems, something must be done to allow business decision-makers to extract the information it contains. For example, "In the first four months of 1995, the New York Stock Exchange processed, on average, 333 million transactions per day" [Schroeder, et. al, 1996]. Considering this volume of data, today's business decision-maker faces the task of sorting through the jungle of data created by information systems. Visualization technologies allow the business decision-maker to separate the "wheat from the chaff."

Recent advances in visualization technologies provide the capability to begin to use human visual/spatial abilities to solve the abstract problems found in business. Furthermore, cognitive fit theory shows that decision making is improved when the information representation matches the problem-solving task [Vessey, 1991]. Representing data suitably in a visual manner, improves the efficiency and effectiveness of the decision-maker, and thus, allows them to separate the information from the "chaff."

The objectives of this tutorial are to introduce visualization technology and to describe its potential for use in business problem solving tasks. To achieve this goal, we define visualization, identify the purpose of visualization, and describe:

- why visualization technology may be appropriate for business problem solving,
- issues related to visualization design, and
- some applications of visualization technology.

A secondary purpose of this tutorial is to raise interest in research in addressing the use of visualization technologies in business. Virtual reality and

visualization technologies already have been deployed in finance [Chorafas & Steinmann, 1995; Schroeder, et. al, 1996; Thierauf, 1995], litigation [Brown, et. al, 1995], marketing [Thierauf, 1995], manufacturing [Chorafas and Steinmann, 1995; Thierauf, 1995], training [Thierauf, 1995], and organizational modeling [Markham, 1998; Wexelblat, 1993]. Yet, does visualization technology improve the effectiveness of business decision making? Are visualization technologies cost effective? Or, are they simply another technology looking for a problem to solve? Obviously, the answer is never a simple yes or no. Studies need to be conducted to guide business decision-makers in determining what business problem solving tasks should be supported by the different types of visualization technologies.

II. VISUALIZATION HISTORY

Visualization is *not* new. For example, cave drawings found in France are over 20,000 years old. The Chinese created the first known maps in the 12th century. However, the first multi-dimensional representations did not begin appearing until the 19th century. Dr. John Snow and Charles Joseph Minard created two of the better examples. In 1854, Dr. Snow plotted cholera deaths in central London. (Figure 1) He marked the location of deaths with dots and of water pumps with crosses. He observed that cholera occurred almost entirely among those who lived near (and drank from) the Broad Street pump. Based on this observation, he had the handle from the pump removed and ended the cholera epidemic. [Tufte, 1983]

In 1861, Minard created possibly the best statistical graphic ever drawn [Tufte, 1983]. This graphic portrays Napoleon's losses suffered during his invasion of Russia in 1812. (Figure 2) The width of the band represents the size of his army. The lighter color band represents the invasion, while the darker band represents the retreat. At the beginning of the invasion of Russia (seen at the left of the graphic) the size of the army was approximately 422,000. Napoleon reached Moscow with about 100,000 men. By the time his army reached the Polish-Russian border, his army had dwindled to about 10,000 men.

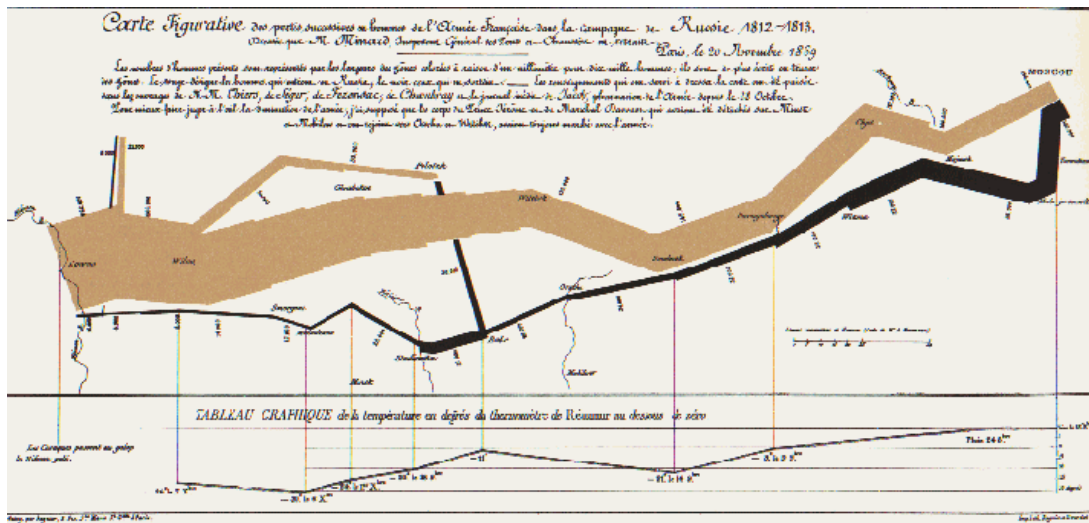Figure 1. Snow's Cholera Graphic [Tufte, 1983, p. 24, © Graphics Press]

Figure 2. Minard's Graphic of Napoleon's Moscow Campaign of 1812
[Tufte, 1983, p. 41, © Graphics Press]

The graphic also shows the temperature scale and dates of the retreat at the bottom of the chart. [Tufte, 1983].

III. WHAT IS VISUALIZATION?

What exactly is meant by visualization? The New Lexicon Webster's Dictionary of the English Language [1989, p. 1100], defines visualization as "a visualizing or being visualized; a mental picture." What is meant by "being visualized?" According to The Random House Dictionary of the English Language [1987, p. 2127] to visualize is "to recall or form mental images or pictures; to make visual or visible; to form a mental image of; to make perceptible to the mind or imagination." These definitions imply that a visualization is a picture of some phenomena. A more appropriate definition is found in The Dictionary of Computer Graphics and Virtual Reality: visualization is "the process of representing data as a visual image." [Latham, 1995, p. 148] The underlying data could represent concrete objects, such as rooms or cars, or the data could represent abstract objects, such as profit, sales, or cost. If the data is abstract, then a visual analog must be created. A typical visual analog is a pie chart or line graph.

The purpose of visualization is *not* to replace good solid quantitative analysis, but instead to allow the quantitative analysis to be focussed [Grinstein and Ward, 1997]. Visualization allows:

- Exploiting the human visual system to extract information from data,
- Provides an overview of complex data sets,
- Identifies structure, patterns, trends, anomalies, and relationships in data, and
- Assists in identifying the areas of "interest"

In other words, visualization allows decision-makers to use their natural spatial/visual abilities to determine where further exploration should be done. This implies that visualization, when used appropriately, can allow the decision-maker to find the information in the data.

Visualization technologies fall into three general classes: scientific visualization, data/information visualization, and virtual reality.

- Scientific visualization, as the name implies, deals with the transformation of data produced through scientific or engineering calculations or experiments into images, e.g., airflow over a wing. [Schroeder, Martin, and Lorensen, 1998]

- Data/information visualization addresses the transformation of non-spatial or behavioral data into visual images that represents an analogy or metaphor of the problem space, e.g., investment portfolio analysis. [VDI, 1997]

- In the context of business information visualization, virtual reality (VR) is simply a 3D, computer-generated, simulated environment that is rendered in real time according to the behavior of the user. [Loeffler and Anderson, 1994] VR has also been referred to as artificial reality, cyberspace, and virtual environments.

The three different classes of VR systems are non-immersive, immersive, and CAVE^{TM} based systems.

- *Non-immersive VR* uses technology such as stereographic shutter glasses to fool the user into believing that the object they see on a two-dimensional surface is in fact 3D.

- *Immersive VR* actually takes the user the next step. It puts the user into the visualization. The Dictionary of Computer Graphics and Virtual Reality [Latham, 1995, p. 71] defines it as:

    "an electronic simulation in which perspective images are generated in real time from a stored database corresponding to the position and orientation of the head of a user..."

    When one thinks of VR, it is normally immersive VR that comes to mind. The CAVE^{TM} is possibly the ultimate immersive VR environment.

- What is a CAVE^{TM}? [Cruz-Niera, et al., 1992] The best image that comes to mind to describe a CAVE^{TM} as a first generation "holodeck." Technically speaking this is not correct. However, it does produce the correct "visualization" of the CAVE^{TM}. In a nutshell, a CAVE^{TM} is a multi-person, room-sized, high-resolution, 3D video and audio environment. It

allows a viewer (the "driver" who wears a location sensor) to move within its display boundaries. The correct perspective and stereo projections of the environment are updated and the image moves with and surrounds the viewer. Currently, there is only one driver. The other viewers in the CAVE^{TM} simply go along for the ride. Also, the CAVE^{TM} provides a sonification capability through the use of computer-controlled speakers. [Kriz, 1997]

Based on the above definitions, business information visualization is simply the use of visualization technologies to visualize business data or information. Of course, business information has been visualized in the form of tables, outlines, pie charts, line graphs, and bar charts for a very long time. However, today business information visualization means the use of multidimensional graphics to represent business-related data or information.

Business information is different than other types of data. Business information is typically abstract, discrete, and multi-dimensional. In addition, business information can be historical or can be generated in real-time. These characteristics make business information visualization difficult.

IV. WHY VISUALIZATION TECHNOLOGY?

Today's business decision-maker suffers from information overload while at the same time underutilizing large amounts of relevant information. The primary reasons for this are [VDI, 1997]:

- Key information is difficult to find or recognize
- Time-sensitive responsiveness is required
- Current DSS tools actually constrain productivity

Since a majority of the brain's activity that deals with processing of sensory data, deals with analyzing visual images, visualization technologies can help resolve this dilemma. [Chorafas and Steinman, 1995] By tapping this innate ability, we may be capable of aiding today's business decision-maker. In this section, we describe why visualization technologies may be appropriate for

business problem solving by overviewing visual cognition, cognitive fit theory, and the types of tasks for which visualization can be used.

VISUAL COGNITION

Much of the research on human cognition shows that visualizations enlarge problem solving capabilities. Visualization applications can enhance the capability to process information that is either unidimensional or multidimensional. Miller's classic paper [1956], "*The Magical Number Seven, Plus or Minus Two: Some Limits on Our Capacity for Processing Information*," describes various experimental results that shed some light on the ability to make absolute judgements in terms of unidimensional and multidimensional stimuli. In relation to visualization, he reports on a set of results that imply that a human's input channel capacity is greater when visual abilities are used. For example, humans are able to distinguish between ten and fifteen levels in determining the location of a marker on a line, seven and ten levels of direction, six and eight levels of line length, five and seven different levels of size, and about nine different levels of color. For unidimensional data, the visual input channel shows much promise for exploitation.

Using multidimensional stimuli, the experimental results were even better. However, the results did not improve as much as was expected. The results relevant to visualization were [Miller 1956]:

- when combining hue and saturation, humans can distinguish twelve different levels,
- when combining size, brightness, and hue, the number of different levels increases to seventeen, and
- when subjects were asked to identify the location of a dot in a square, they were capable of differentiating about 24 different levels.

These findings suggest different parameters in the visual channel that can be exploited to increase substantially the amount of data that decision-makers process without overload.

A more recent area of research is in the area of visual imagery [Kosslyn, 1980; Shepard and Cooper, 1982]. Visual recall seems to be better than verbal recall, i.e., a picture really is worth a 1000 words. Furthermore, image processing apparently is done in 3D. However, imagery is dependent on perception, i.e., how the objects were learned (visual images on visual perception; auditory images on auditory perceptions, etc.). Attempt to perform the following tasks:

- Imagine your kitchen sink - describe how to turn on the hot water
- Imagine your home - count how many windows are in your home
- Name the major cities on the east coast of the United States
- Describe your "waking-up" routine

In each of these tasks, the underlying model could be based on an image. Did you "see" your kitchen sink before recalling how to turn on the hot water? Did you "walk through" your home to count the windows? Did you "use" a map to identify the major cities? Did you "see" yourself waking up to identify the tasks that you perform each morning? From a practical point of view, it really doesn't matter how images are stored and recalled. What matters is that humans seem to have a natural ability in using images that can be exploited to improve business decision making.

Imagery based research also found that the mental models used in simulating things related to vision or sound tend to draw upon real-world analogies. When this occurs, images must behave according to "time-space" or physics laws. Furthermore, concrete or "natural" images (those that have a real-world counterpart) are faster to retrieve than abstract images. This result of course has a bearing on business information visualization. What is a "natural" image of business information? Visualize income, return-on-investment, wealth, sales, or almost any information of interest to business decision-makers. We revisit this issue below when we describe visualization representations.

COGNITIVE FIT THEORY AND VISUALIZATION PROBLEM-SOLVING TASKS

Larkin and Simon [1987] found that diagrams can be superior representations to written representations. They give three reasons why this seems to be true:

- Diagrams can group all related information together

- Diagrams can use location to aid in information search

- Diagrams can aid in many perceptual inferences.

Their explanation for this phenomenon is that, from a cognitive processing perspective, diagrams support efficient computational processes. However, the user of the diagrams must be capable of executing these processes.

Cognitive Fit Theory [Vessey, 1991] has been used to explain why graphs are sometimes better than tables for supporting decision making. In its basic form (Figure 3), Cognitive Fit Theory states that a solution to a problem is "an outcome of the relationship between the problem representation and problem solving tasks." [Vessey, 1991, p. 220]. The better the "fit" is between these two constructs, the more effective and efficient the problem solving process. Therefore, when developing information visualizations, the developer must pay attention to the tasks performed by the decision-maker if the visualization is to be successful.
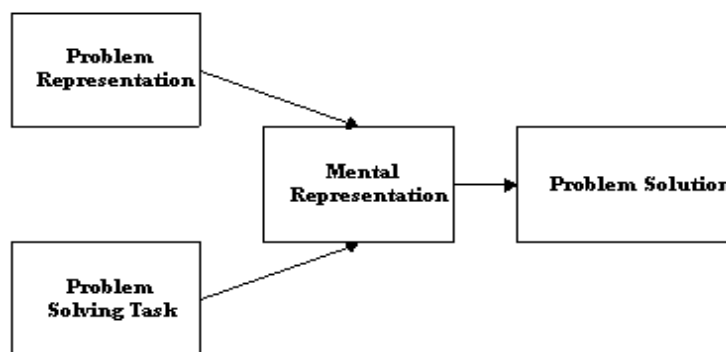
Figure 3. Cognitive Fit Model

The problem solving tasks that visualization technology can address are: exploratory, confirmatory, and production [Grinstein and Ward, 1997].

- Exploratory tasks tend to be dynamic. Users normally search for structure or trends that can be gleaned from the visualization or they are attempting to create or test hypotheses about the underlying information.

- Confirmatory tasks tend to be fairly stable and predictable. In this case, the users normally attempt to confirm or refute hypotheses.

- Production-based tasks are reporting systems. The users already have a validated hypothesis and are using a visualization-based report.

V. VISUALIZATION DESIGN

To design effective visualizations, the designer must first understand the data that will be used as the basis of the visualization. The designer must identify the sources of the data, the level of completeness of the data, and the type of the data. Is the data discrete or continuous? Is it located in a historical database or is it coming in on a real-time data feed? What is the dimensionality of the data - 1D, 2D, 3D, etc? What is the scale of the data (Nominal, Ordinal, Interval, Ratio, or Absolute)? How reliable is the data? All of these questions need to be answered to understand the data well enough to design useful business information visualizations. Data modeling approaches [Teorey, 1990] can be used to address these questions.

In many ways, the design of a visualization is very similar to the design of a user interface. Accordingly, paying attention to user interface guidelines is essential. Shneiderman [1998] identifies three basic principles. First, the designer should be aware of the diversity of the potential users and the tasks that the user interface is to support. One of the primary mantras of user interface design is "Know thy user." From Shneiderman's perspective, "Successful designers are aware that other people learn, think, and solve problems in different ways." (p. 67). Consequently, the designer must understand the diversity of the users and their tasks. This can be accomplished using task analysis [Bailey, 1996], observation techniques [Spradley, 1980], interviews [Spradley, 1979], or scenario-based design techniques [Carroll, 1995].

The second principle suggests eight heuristics that any user interface designer should follow. First, the user interface should be consistent. This can be difficult depending on the context. From a visualization perspective, the interactions between the decision-maker and the system should be the same across different systems. Also, similar types of data should be visually represented similarly across systems. Second, the user interface designer should encourage the use of shortcut key sequences for frequently performed actions, e.g., control+s for saving a file. Third, every action taken by a user should have an explicit response from the system, i.e., the system should provide meaningful feedback. Fourth, dialogs should provide closure. Dialogs should inform the user as to the amount of progress the user has made in performing their task. This heuristic relates to the previous heuristic. Fifth, the designer should design for user errors. By doing this, the designer builds into the system an error handling capability. Sixth, the system should provide an easy way for the user to undo their actions. This allows the user to correct their errors by backing them out. Seventh, be sure that the user has the sense of being in charge. Many systems in the past have put the computer in charge instead of the user. From a visualization perspective, the user should be the initiator of all actions and the computer should simply be the respondent. Eighth, be aware of short term memory constraints (Miller's seven - plus or minus two chunks).

The third and final principle is systems should prevent errors. He suggests three error prevention techniques. First, it is possible that commands come in pairs, e.g, many HTML tags have both a beginning and an ending tag. In these cases, the system could automatically insert or correct the matching pair. Second, there may be a set of commands typically used in sequence. The designer could create an "aggregate" command that groups the sequence of commands. This would prevent the user from having to remember the entire sequence. Third, the system could support automatic completion of a command or provide a user with a set of relevant commands from which to choose.

Kosslyn [1994], an imagery researcher, states three maxims to guide graphic display design:

1. The Mind Is Not a Camera
2. The Mind Judges a Book by Its Cover
3. The Spirit Is Willing, But the Mind Is Weak

Many people assume that the mind sees things much like a camera does. However, the mind is not a passive observer. It actively organizes data to make sense of them. Kosslyn points out that our visual system seems to have a number of separate "input channels" in which to gather visual information. The different channels are sensitive to different types of changes. From a visual design perspective, we should utilize these distinct channels, otherwise, we may "overload" the decision-maker.

The second maxim dictates designing a visual representation that is "natural." By natural, we mean that the visualization is capable of being associated with the "real-world" entity at an intuitive level. In this manner, the decision-maker can use a recognition-based approach instead of one that requires recall. (Recognition-based tasks are computationally less expensive.)

Kosslyn's final maxim addresses the same point that Miller did, i.e., we have a limited amount of information that we can retain in short term memory at one time. The only way to increase this amount is by "chunking" the information being stored. Visualizations, through the use of multiple input channels, can aid the decision-maker in the chunking of the relevant information. Of course, if the visualization is poorly designed, (i.e., it does not take the above into consideration) it can cause much confusion.

Tufte [1983, 1990] provides six objectives that any graphic should meet:

- First, he suggests that we should simply show the data. In many cases, graphic designers tend to show various aggregations of the data instead of the data itself. In most cases, allowing the user to perform the aggregations visually provides greater insight into the underlying structure of the data.

- Second, he suggests that we insure that the user is thinking about the substance of the graphic and not the graphic itself. From a business information perspective, many of the standard techniques (or variations of

them) are more than sufficient. If the user has to think about the graphic representation instead of the underlying data, the graphics representation has failed.

- Third, avoid any unnecessary decorations. Adornments to a graphic rarely provide additional information. Normally they do nothing but divert the attention of the user. "Cute" or "clever" graphics will only distract the user from their problem-solving task.

- Fourth, Tufte suggests compressing as much information into as small a space as possible. This point relates back to the results reported by Miller [1956], Kosslyn [1980], and Shepard and Cooper [1982]. Through properly designed graphics, it is possible to support the user's "chunking" of information. Obviously, the previously mentioned points of Shneiderman [1998] and Kosslyn [1994] must be taken into consideration.

- Fifth, graphics should be designed to encourage the user to make comparisons between different pieces of data. Users are capable of doing comparisons with graphics much better than using them for absolute judgements. [Grinstein and Ward, 1997]

- Tufte's sixth and final objective is that graphics should provide views of the data at many levels of detail.   This principle relates to the "Drilldown" and "Level-Of-Detail" capabilities of visualizations. With these capabilities, the designer can allow a broad overview of the data to be given and, at the same time, allow the user to have access to the detailed data that underlies the overview.

Based on Tufte's guidelines, visualization designers can choose an appropriate visual representation (Section VI). The user should find the metaphor chosen easy to understand. In multidimensional visualization, normalization of the underlying data is required. Otherwise, scale issues and skewness issues could produce bad visualizations. Furthermore, the designers should map the data/information to the components of the visualization. The primary components of a visualization are based on size (height, length, width) and location (x-axis, y-axis, z-axis). Secondary components could be animation (based on time) and

color. However, visualization components such as transparency and texture are not as easily interpretable.

VI. VISUALIZATION REPRESENTATIONS (METAPHORS)

Possibly, the most difficult aspect of designing information visualizations is the choice of representation (or metaphor). The reason that this choice is so difficult is that deciding what is a "natural" representation for business data is not straightforward. However, information visualization designers have created representations that can be used as a beginning point in creating new information visualizations. Beyond the above guidelines and sample representations, there are really no aids for the designer in choosing the correct metaphor. It is possible that good information visualizations are not only task dependent, but they also may be domain dependent. What is needed is a good taxonomy of domains, tasks, and visualizations.

A good starting point is to look at business charting techniques. Business decision-makers are already familiar with these types of diagrams. Today, bar charts, line graphs, pie charts, and other typical business diagrams may be as a "natural" representation as is possible. In this case, "natural" is a misnomer. These formats have simply been learned. The formats can be modified and extended to deal with multidimensional data. A good deal of additional research is required in this area.

In this section, we describe a sample of the visual representations created by information visualization designers. For a more complete set of examples see Bertin [1983], Harris [1996], Keller and Keller [1993], Nielson et al. [1997], and OLIVE [1997]).

KIVIAT DIAGRAMS

Kiviat diagrams (Fig. 4) have been used for many years in computer performance evaluation [Kolence and Kiviat, 1973]. A Kiviat diagram allows the depiction of relationships among multivariate data. Each value of each measure

is shown on its own individual axis. For example, if we have five separate measures, the Kiviat diagram would have five distinct axis (radii). The value for each measure for the entity of interest is plotted on the appropriate axis. The points are then connected. The pattern that is formed is the information visualization. To compare one entity to another, one compares the patterns of the separate entities. These diagrams are also known as radar charts, star graphs, spider graphs, and star glyphs.
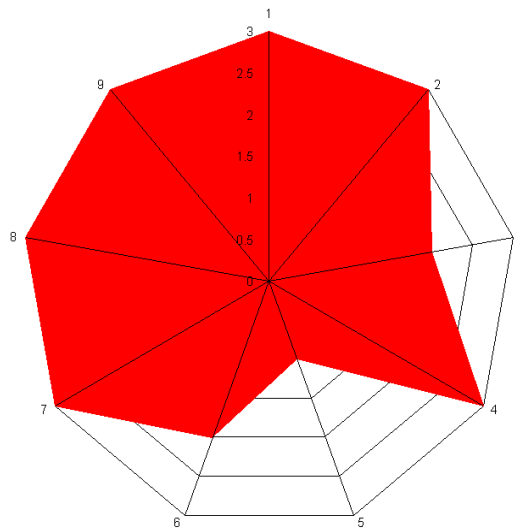
Figure 4. Kiviat Diagram

PARALLEL COORDINATES

Parallel Coordinates (Figure 5) is another multivariate technique that has been used for a long time. Recently, this approach has been used in the area of visual data mining [Inselberg, 1997]. As shown in Figure 5, like a Kiviat diagram, each measure is plotted on its own individual axis for each entity. In this case, the pattern is a line instead of a polygon, which makes looking for similar patterns across multiple entities straightforward. For example, looking at the last two variables in Figure 5 demonstrates two separate groupings of entities - one in red and one in blue.
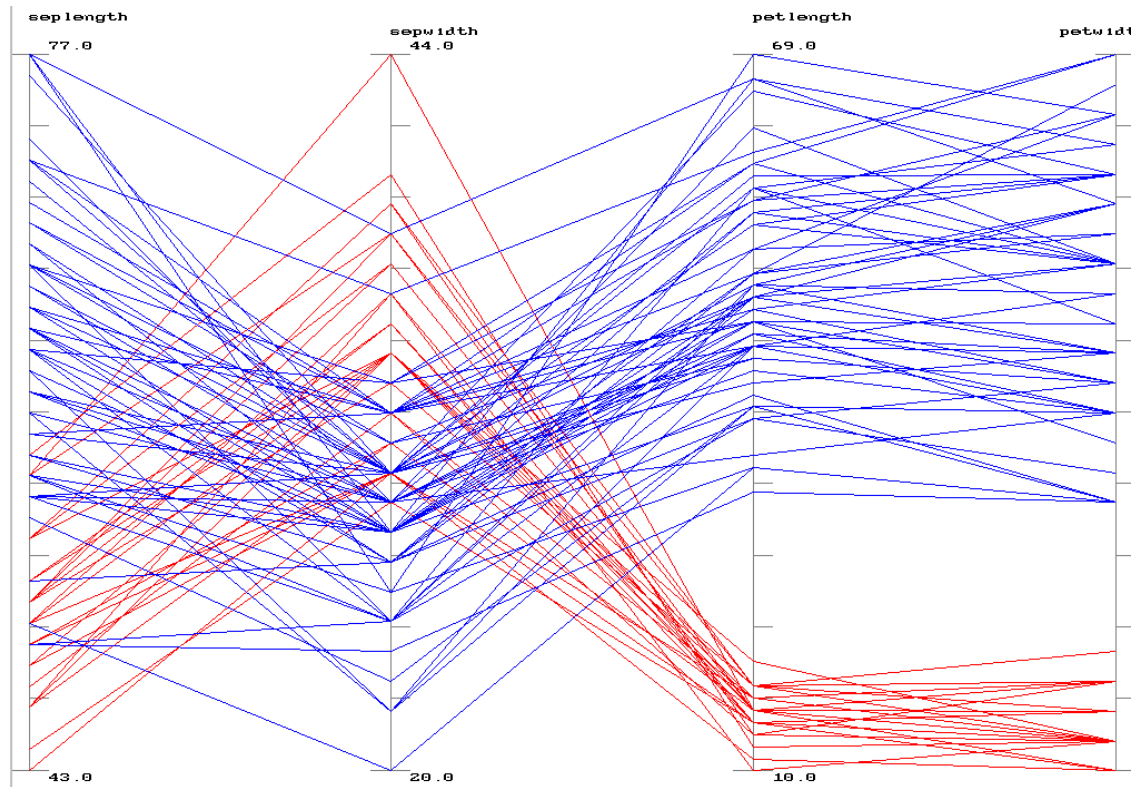
Figure 5. Parallel Coordinates

3D SCATTERGRAM

A 3D scattergram (Figure 6) is an extension to the typical 2D scatterplot that one finds in most statistics packages. In this case, one can represent up to four separate measures on each entity: one for each axis (x, y, and z) and color. However, one major problem with this approach is that it tends to be difficult to determine precisely the location of each specific value. In many cases it is necessary to add reference data, e.g., lines from each value to their respective axis values and the addition of a color map. Otherwise, the interpretability of the scattergram may be problematic.
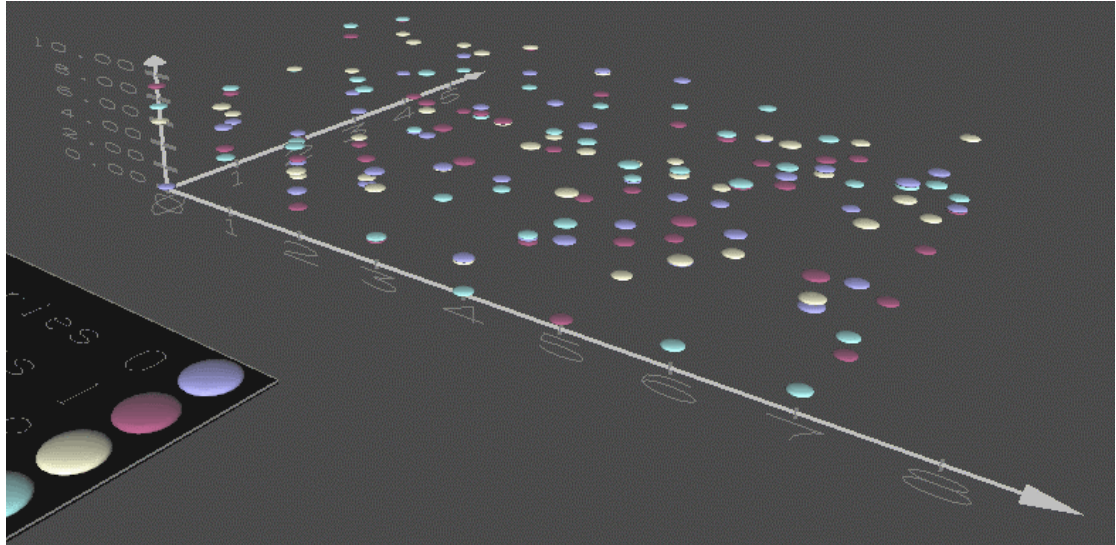
Figure 6. 3D Scattergram

3D LINE GRAPH

A 3D line graph (Figure 7) is an extension to the typical 2D line graph. This graph allows the representation of up to four separate measures for the entity of interest. In this case, the line spirals through the three dimensions (x, y, and z). As the fourth measure changes, the color of the line changes. In this case, since only one entity is graphed at a time, the results are easier to interpret than the 3D scattergram. However, like the 3D scattergram, this representation really needs the addition of reference data and a color map to be usable.
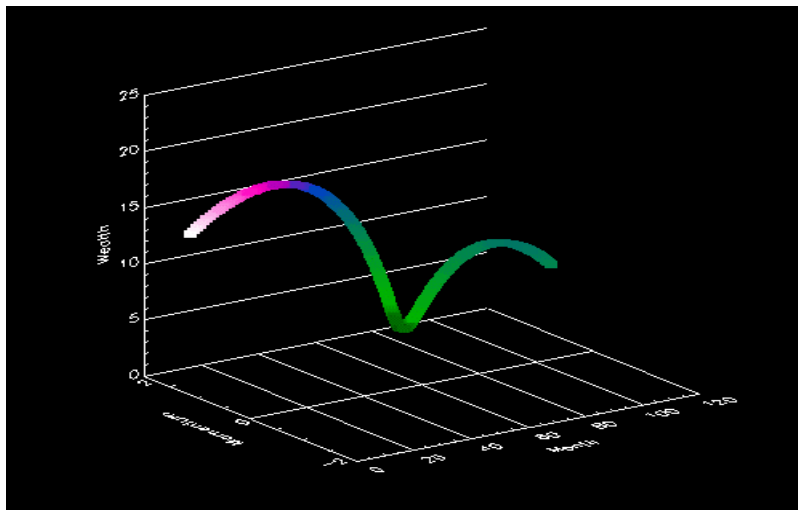
Figure 7. 3D Line Graph [Dull and Tegarden, 1998]

VOLUME RENDERING

Volume rendering (Figure 8) requires a 3D data set. This approach has been used as a scientific visualization technique. However, Becker [1997] of Silicon Graphics has recently used it to represent data stored in a relational database. In this work, he plots aggregated data (education level, occupation, and hours worked) into the 3D space and assigns color to the dependent variable (income). Opacity of the visualization is based on the number of observations contained in that location. He also assigns an additional variable (age) to an external slider to use as the basis for a visual query. Based on this work, volume rendering may now turn out to be a reasonable alternative to other multivariate representations.
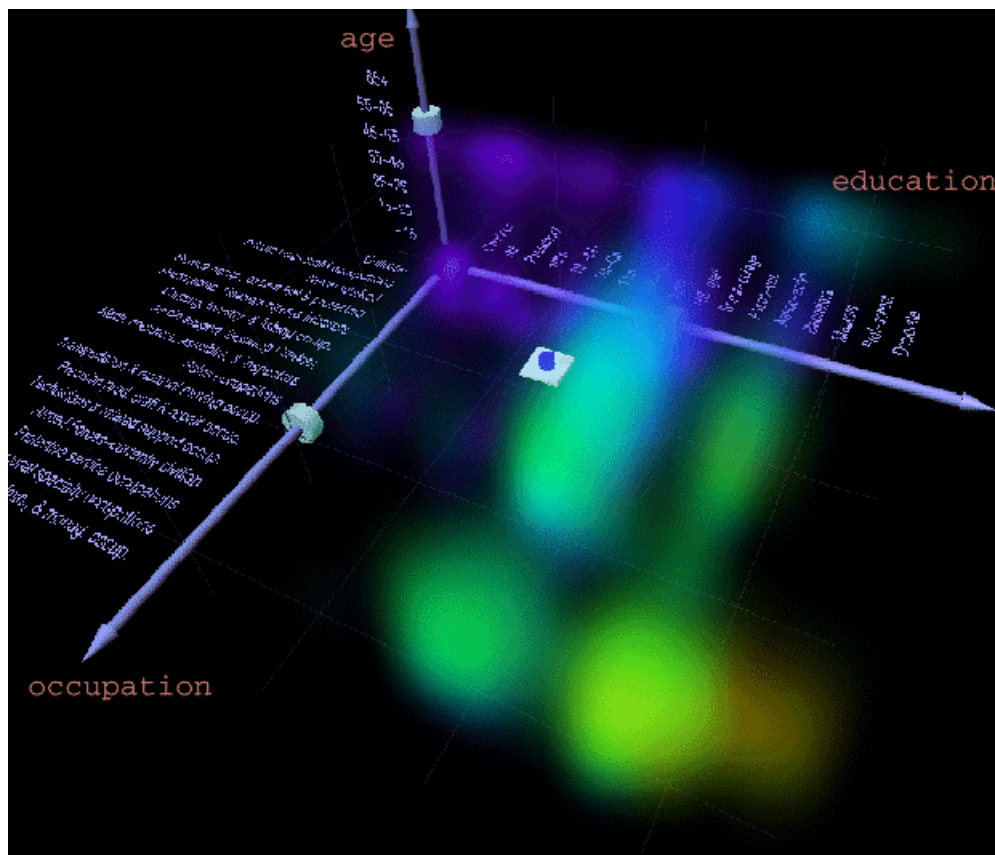
Figure 8. Volume Rendering [Becker, 1997, p. 124, © IEEE]

FLOORS AND WALLS

The floors and walls representation (Figure 9) is a form of a room metaphor. In this representation, information is assigned to various business graphics and is displayed on a wall of the room or on the floor of the room. This representation allows a great deal of information to be placed in a relatively small space, i.e., it supports one of Tufte's guidelines. Also, it supports the decision-maker with graphics that the decision-maker is familiar, e.g., pie charts, bar charts, line graphs, and other typical business charting approaches. This representation supports both exploratory and confirmatory decision making tasks. In these types of tasks, the decision-maker would navigate through the landscape to find the information to create new or test held hypotheses.
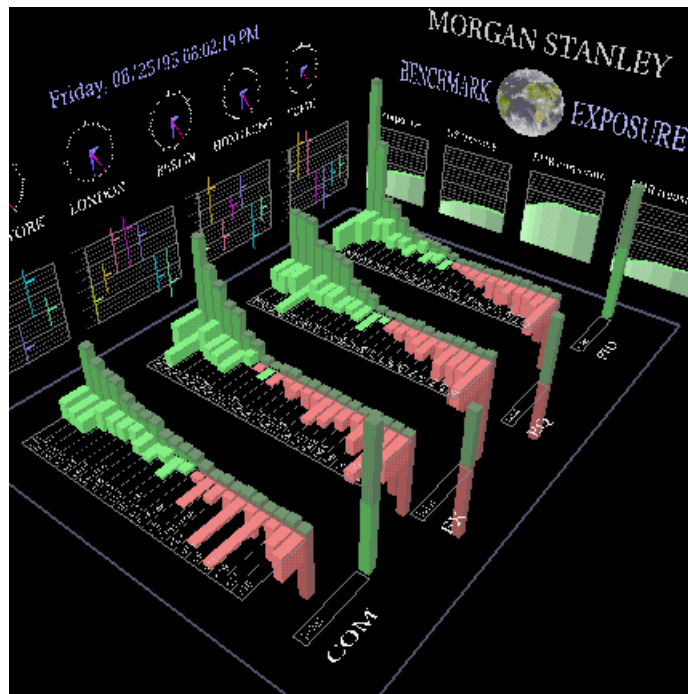
Figure 9. Floor and Walls (courtesy Visible Decisions, Inc.)

MAPS

Maps (Figure 10) are a potential "natural" representation for entities that can be analyzed geographically. For example, if a regional (state) manager would like to see how their region (state) is performing in comparison to other

regions (states) in terms of retail sales, the manager could look at a map-based "bar" chart type of visualization. One drawback of this particular visualization is that only one measure can be visualized at a time. However, this representation could be combined with a floor and wall type of representation to allow a "drill down" process. In this manner, a map-based representation can become a true multivariate representation.
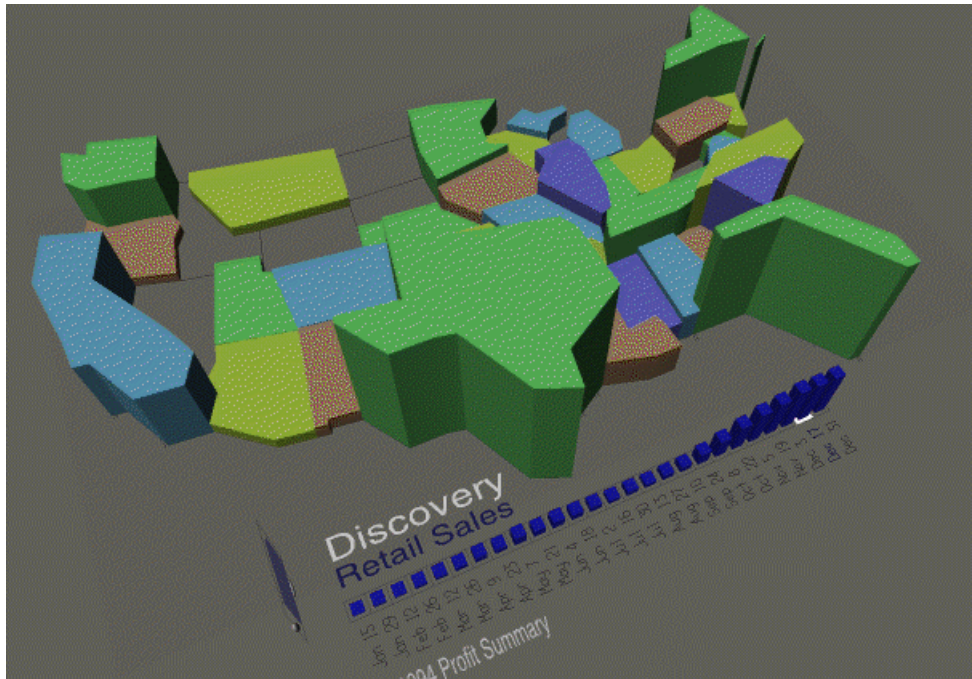
Figure 10. Maps (courtesy Visible Decisions, Inc.)

SURFACES

Surface representations (Figure 11), like volumes, have been used primarily in the area of scientific visualization. However, the idea of traversing the peaks and valleys of a business information landscape is appealing. We can imagine a decision-maker scanning the surface to find "interesting" patterns. However, since surface representations are continuous in nature, not discrete, they should only be used when representing a continuous variable. As such, their usefulness for most typical business information may be limited. More research to determine the usefulness of this type of representation appears to be necessary.
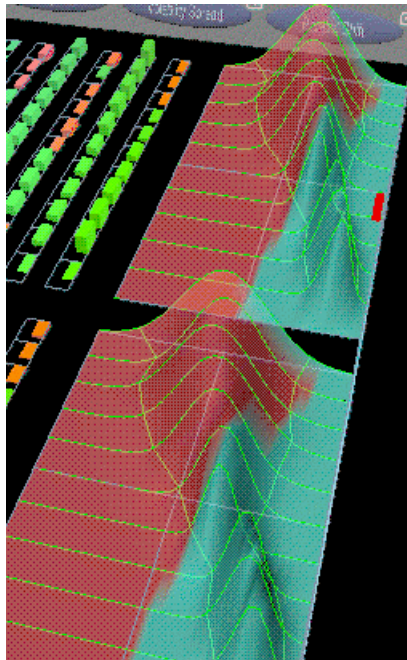
Figure 11. Surfaces (courtesy Visible Decisions, Inc.)

VII. VISUALIZATION APPLICATIONS

This section describes several applications of information visualization technologies. Table 1 lists typical problems that have been solved using this technology.

Table 1. Typical Business Application Domains

Financial Risk Management	Industrial Process Control
Operations Planning	Capital Markets Management
Military Strategic Planning	Network Monitoring
Marketing Analysis	Derivatives Trading
Fraud/Surveillance Analysis	Portfolio Management
Actuarial Modeling	Customer/Product Analysis
Budget Planning	Operations Management
Economic Analysis	Fleet/Shipping Admin

FINANCIAL 100

The example shown in Figure 12 was created using C++ and In3D from Visible Decisions, Inc. The figure shows an interactive information visualization of data related to the Financial 100. It uses a floor and wall metaphor. The revenue of each firm is plotted on the x-axis, while on the y-axis (the one going back through the landscape) rank in 1995 is plotted. The z-axis, the walls, and color are used to represent the profit of each firm. By looking at the landscape, we see that even though some of the firms are ranked high, they have a relatively low profit. We also see that many of the Financial 100 had a loss in 1995. If the user needs to look at the data from a different perspective, the user can navigate through or rotate the visualization. Finally, there is a drill-down ability within this visualization. In this snapshot, we have "brushed" the number one firm in the list to lookup the details about that firm (General Motors). Brushing is simply moving the mouse over the entity of interest. In this case, brushing displays the underlying database entry for the firm.
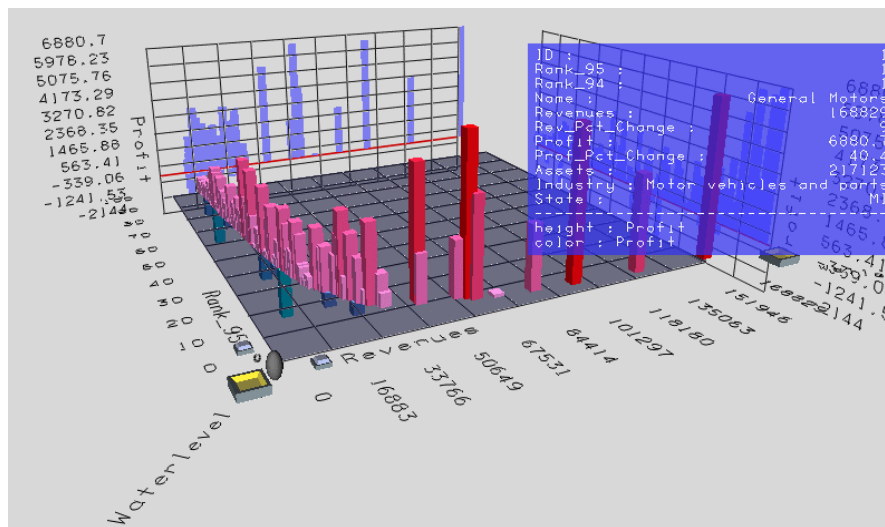
Figure 12. Financial 100 (courtesy Visible Decisions, Inc.)

PUBLIC OPINION POLLING

Public opinion polling can be an expensive endeavor. However, with the World Wide Web and 1-800 numbers, it is possible to have voters who are interested in a particular issue to "voice" their opinion. Of course, random

sampling issues would apply to this type of poll. (On the other hand, with today's voter apathy, this type of polling sample may be more accurate than true random samples.) For example, on CNN Interactive, there are the "Quick Vote" pages. CNN posts a set of questions that they believe potentially are newsworthy. In the CNN example, only a simple bar chart displays the results. However, if the user of the poll would like to see how different regions of the country voted on a particular topic, additional information (such as state, city, or congressional district) would have to be collected. The public opinion polling example shown in Figure 13 was created using C++ and Discovery from Visible Decision, Inc. It is a prototype of a public opinion polling visualization. The user can "click" on any area on the map to "drill-down" to the results in which they are interested. e.g., state, city, or district. In this case green represents yes, red represents no, yellow is undecided. The height of the bars represents the number of yes, no, or undecided votes. In this example, the user can quickly see how the different regions, states, and districts are going. Finally, the user of this landscape can navigate through or rotate the visualization to view the visualization from a different perspective.
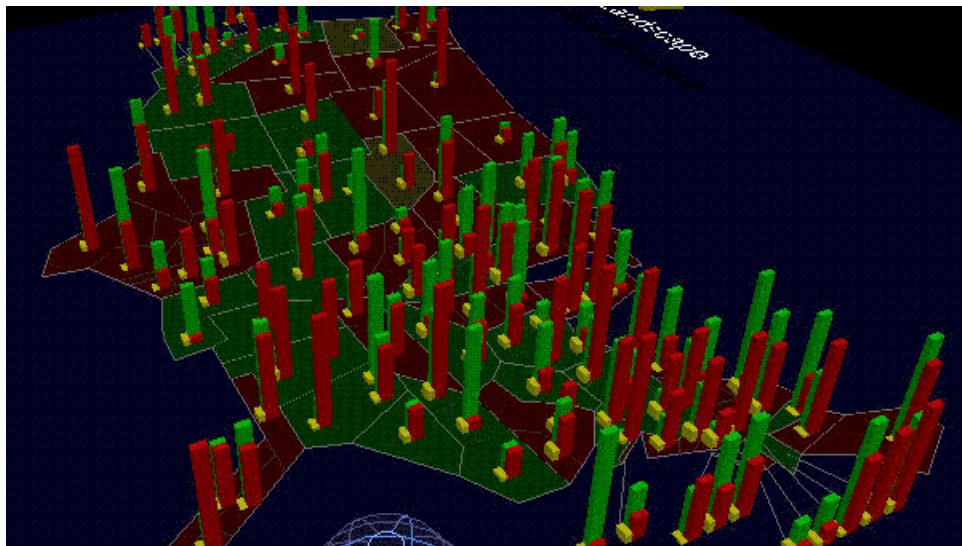
Figure 13. Public Opinion Polling (courtesy Visible Decisions, Inc.)

RETAIL SALES

The information landscape shown in Figure 14 was created using C++ and In3D from Visible Decisions, Inc. It enables a manager of a retail chain to observe sales patterns over an entire year within a geographical context. In this example, there are many interactive controls. Within the landscape, it is possible to change the variable being graphed (see x-y-z axis indicator on left side of landscape). Currently, sales are the only measure being plotted. However, it is possible to display more than one variable at a time. Also, there is a set of "VCR" controls at the lower right portion of the landscape. These controls allow the user to animate the visualization by having the sales plotted for each date (see the time line at the bottom of the visualization) contained in the database. If the user wants to "drill down" to find out more information about a particular state, the user can either "brush" the state (see blue box data on Virginia) or the user can use an external control located at the far right side of the application to choose a detailed view (one that is similar to the polling example). External range sliders allow the user to determine what underlying data values are to be displayed in the landscape. Finally, this landscape also can be navigated and rotated.

CYBERCAMPUS

The VR application shown in Figure 15 was created by NTT Human Interface Laboratories using C++ and WorldToolkit from Engineering Animation, Inc. This example provides a common virtual space in which each user can move about freely and interact with other participants and the environment. Video and audio capabilities actually project the face and voice of each user onto the avatar representation of the user in the virtual world. This approach allows realistic multi-user telecommunication. NTT and its partners hope to evaluate the technical, social, commercial, and psychological aspects of this type of service. Eventually, NTT plans to provide a shopping mall of commercial applications, including educational, entertainment, business and retail options. The demonstration in Figure 15 is a virtual music store (Tower Records) where
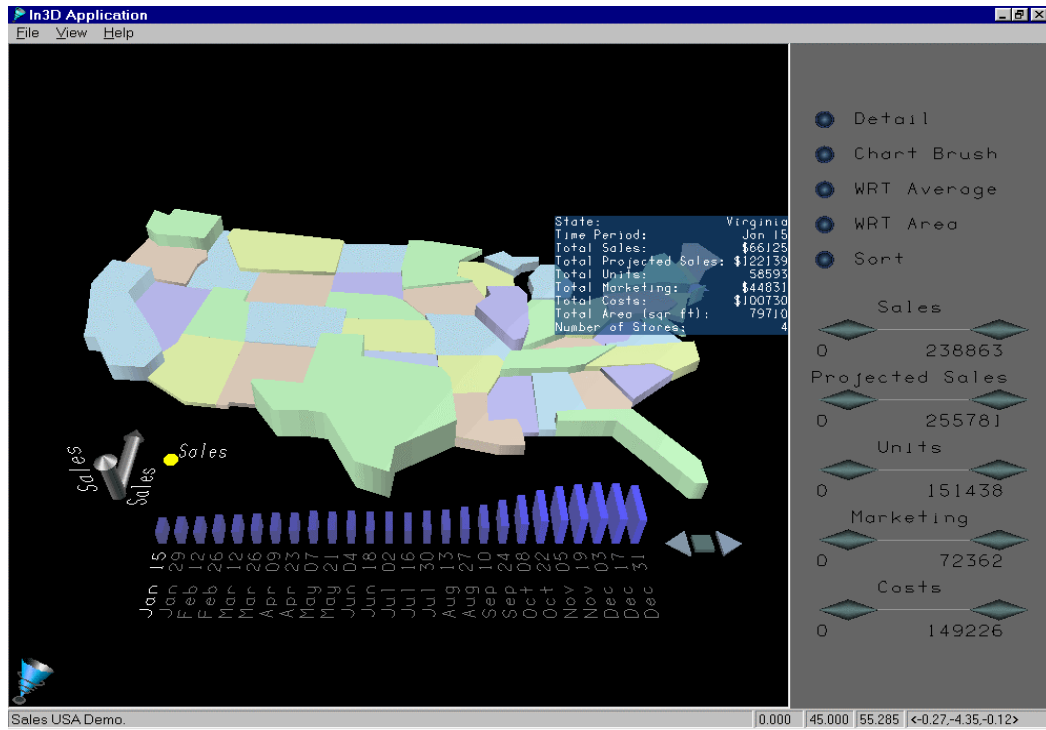
Figure 14. Retail Sales (courtesy Visible Decisions, Inc.)

customers can preview audio, video and other media associated with Top 10 CDs. Customers can make a selection and purchase the CD from a real sales associate located in the virtual space.
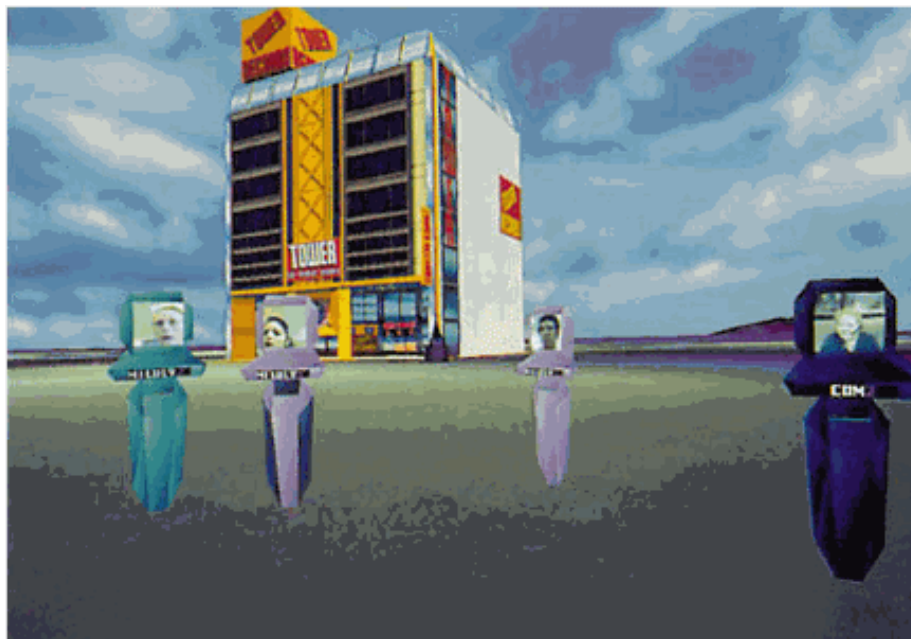

Figure 15. Cyber Campus (courtesy Engineering Animation, Inc.)

VIRTUAL CAMPUS

For the past two years, David Monarchi has been heading up the Integrated Immersive Learning Environment (IILE) project in the College of Business at the University of Colorado at Boulder. The IILE uses multimedia, world wide web, virtual reality, and collaborative groupware technologies to support student learning. The different technologies used allow different students to use different approaches to learn the same material. Thus, the IILE supports different learning styles. Currently, the IILE has been used to create a virtual campus that supports a set of classes at the University of Colorado (see Figure 16). For example, in BCOR 100 - Business Computing Skills, the student may "attend" the class at the student's convenience. The student can walk through and interact with a virtual computer or virtual computer network. The student can go to office hours that are supported using email or a threaded discussion forum, for asynchronous office hours, and chat rooms or Microsoft's NetMeeting software for synchronous office hours. However, the centerpiece of the IILE is the Active Worlds browser created by Circle of Fire, Inc. The Active Worlds browser more fully supports the immersion of the student into the learning environment.
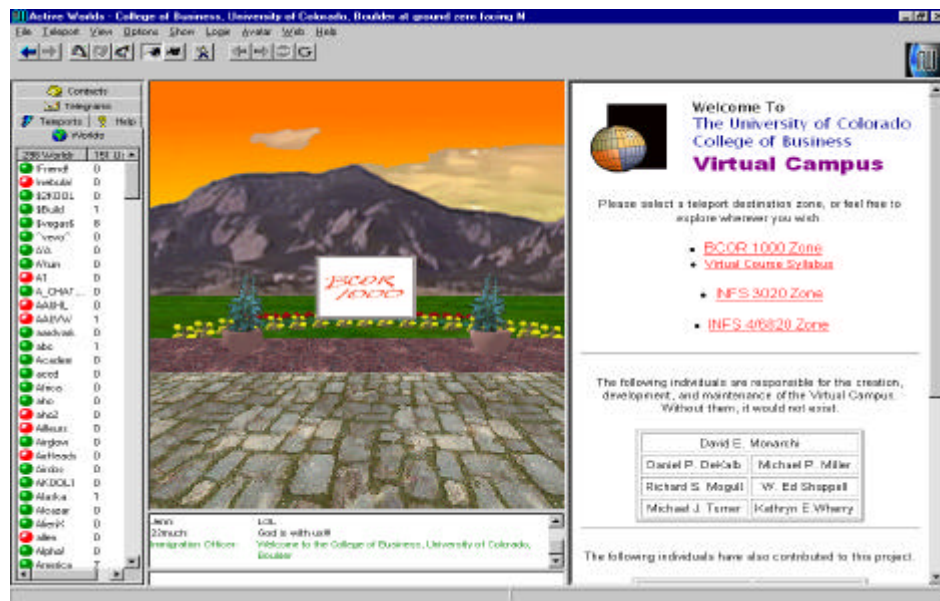
Figure 16. University of Colorado's Virtual Campus (courtesy David Monarchi)

CATERPILLAR CAVE-BASED SOFT PROTOTYPE

This application (shown in Figure 17) was built by Caterpillar, the world's leading manufacturer of earth moving and mining equipment, and the National Center for Supercomputing Applications (NCSA) using C++ and WorldToolKit from Engineering Animation, Inc. In this case, a CAVE^{TM} simulation was built. The simulation allows Caterpillar to build and test soft prototypes of future vehicles. Caterpillar found that making changes to physical prototypes tended to require throwing away the current prototype and building a new one from scratch. This new approach is a sophisticated use of VR in industry. Operators sit on a platform that is equipped with controls like those found in a real cab. The controls are hooked into the CAVE^{TM}. When the prototype needs to be modified, the C++ code is simply changed. This approach allows the new machine to be assessed from within the virtual machine.

Figure 17. Caterpillar CAVE^{TM} Prototype (courtesy Engineering Animation, Inc.)

VIII. CONCLUSIONS

Information visualization technology provides the information systems developer with a new set of tools in which to support the business decision-maker. In this tutorial, we introduced visualization technology by putting

visualization into a historical context, defined visualization, described the purposes of visualization, and provided some justification as to why visualization technology should be investigated. We also provided guidelines to designing information visualizations and choosing visualization representations. Finally, we described a set of typical visualizations that have been created to aid decision-makers. However, there is very little evidence available that suggests which type of business problems should be addressed with visualization technologies.

Visualization technologies have been used in many areas of business, e.g., finance, marketing, and training, and they have been used to support many different types of tasks, e.g. exploratory and confirmatory tasks. However, it is still unclear where this technology may be most effective. As Cognitive Fit Theory suggests, we need to match the problem representation (visualization technique) to the problem solving task. To help address this state of affairs, a taxonomy of business problem domains, problem solving tasks, and visualization techniques would be useful.

With visualization technology, new approaches to solving business problems arise. Decision-makers can fly over or swim through their data. Or, would a decision-maker prefer to climb a mountain or go spelunking? Or, are the more traditional business charting techniques, or their 3D extensions, sufficient? Or, are there new visualizations that need to be created that would be more "natural?" Only time will tell how these technologies impact business problem solving. However, in the meantime, there are many opportunities to conduct research to address these questions. The results of the research can be used to guide the business decision-maker and information systems developer through the visualization landscape. These studies can range from surveys to experiments to systems development efforts.

ACKNOWLEDGEMENTS

Aspires Program (Research and Graduate Studies at Virginia Tech) and the ATT Center for the Scientific Visualization of Organizations (Virginia Tech) for financial support of this research program. Finally, the author acknowledges David Monarchi, Engineering Animation, Inc., and Visible Decisions, Inc. for providing material presented in this tutorial.

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EDITOR'S NOTE: The following reference list contains hyperlinks to World Wide Web pages. Readers who have the ability to access the Web directly from their word processor or are reading the paper on the Web, can gain direct access to these linked references. Readers are warned, however, that
1. these links existed as of the date of publication but are not guaranteed to be working thereafter.
2. the contents of Web pages may change over time. Where version information is provided in the References, different versions may not contain the information or the conclusions referenced.
3. the authors of the Web pages, not CAIS, are responsible for the accuracy of their content.
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