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Visualization of Complex Multi-Dimensional Accounting Information

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Abstract

The relationship between three visual representations of multidimensional data and the subjects' ability to make predictions based on the data was investigated. The visualizations were based on the simulated output of a momentum accounting system. Subjects made predictions based on the visualizations. The subjects using a rotatable three-dimensional image were found to provide the most accurate predictions. The subjects using a two dimensional representation were found to take the least amount of time for their predictions.

Introduction

It has been proposed that there should be an extension of double-entry accounting that would consider a third dimension of accounting data -- the time effect of accounting entries. This extension, commonly referred to as "momentum accounting," would include information relating to the wealth of an organization and the corresponding rates of wealth change (Ijiri, 1982, 1986). When compared to that of traditional double-entry accounting, momentum accounting has a higher level of complexity (Fraser, 1993). Momentum accounting increases the complexity of an accounting system by expanding on the single-dimension stock (assets and liabilities) and two-dimensional flow (revenues and expenses) concepts, by adding a third dimension (time) and, therefore, a corresponding third component of each entry. In momentum accounting, decision-makers consider wealth, the rate of wealth change (momentum), and the rate of momentum change (impulse) in wealth.

In this study, we only focus on making decisions within a multi-dimensional environment, rather on the specifics of a momentum accounting system. As such, we deal with the output of a momentum accounting system. If we could represent the momentum accounting information in a manner that was suitable, could we improve the efficiency and effectiveness of the decision maker? Cognitive fit theory tells us that decision making is improved when the information representation matches the problem space representation to the problem solving task (Vessey, 1991). As such, it seems that to improve the plight of the decision maker, we should match the dimensionality of the representation with the dimensionality of the data.

Research Design and Methodology

Three visualizations were used in the experiment, with each subject being exposed to only one of the three types. The first representation (R1) is a two-dimensional line graph, demonstrating the functions of wealth, momentum and impulse independently. The x-axes, measured in months, ranged from one through one hundred-twenty for each of the representations. The y-axes range, measured in dollars, varied based on the individual companies used for data. Each graph contained three lines, with each line representing a function for the wealth, momentum or impulse of a company. Because of the nature of the functions (the derivative relationships among wealth, momentum and impulse), it was necessary to multiply momentum and impulse by constants to allow all three functions to be displayed on the same graph in a meaningful manner. Each line on the visualization was displayed in a unique color.

The second visualization combined the three 2-dimensional lines from the first representation into one 3-dimensional representation (R2). This was accomplished by creating a 3-dimensional function by adding a z-component and color to a 2-dimensional function. In the new representation, time (month) was maintained as the x-axis and wealth as the y-axis. Momentum was added as the z-axis and the color of the line at any point on the line represented the impulse for a company at that point in time. A line was plotted for the same time range used in the 2-dimensional representations. This representation was displayed from a position of 30 degrees above the xz plane and 35 degrees to the left of the yz plane.

The third representation (R3) was identical to the R2 representation except that the subjects could rotate the image to view the data relationships from different perspectives. The vertical rotation was allowed for 360 degrees (completely around the y-axis) and the horizontal rotation was allowed for the 180 degrees (the top half of the sphere divided by the plane xz).

Hypotheses Development

Numerous studies have shown that graphical formats may generate “better” decisions than those based on traditional accounting formats (Anderson & Kaplan, 1992; Anderson & Reckers, 1992; MacKay & Villarreal, 1987; Stock & Watson, 1984). Wickens, Merwin and Lin (1994) indicate that extraction and retention of data is superior for 3D images over 2D images. Therefore, it was expected that R1 would be associated with the lowest subject performance. Pani (1993) reports that the angle of rotation affects the comprehension of an object that is presented within a 3D representation. This suggests that R3, should be associated with the highest subject performance. As such, our first hypothesis is:

H1: Increasing the dimensionality of the visualization should increase the accuracy of the predictions.

In addition to prediction accuracy, the time to make a decision is important to the decision process. Benbasat and Dexter (1985) suggested that when using multiple forms of information representation to solve problems, differences in time to solve problems may exist. Cooper (1990) reports that when presented with a 2D representation of a 3D problem, subjects mentally create a 3D representation. This suggests that subjects using R1 should require a longer time period to answer the experimental questions (their time includes a mental conversion to a 3D representation). Subjects using R3 should have the lowest decision-making times, because the information is presented in a format that shows the relationships among the data. As such, our second hypothesis is:

H2: Increasing the dimensionality of the visualization should decrease the time to make predictions.

The subjects in this experiment were selected from senior business school students at a major eastern state university. The students are a relatively homogenous group with basic training in financial decision-making. The usable sample consisted of 124 subjects allowing for the assignment of approximately forty students to each of the case groups.

Results

The experiment yielded twelve wealth predictions (three for each of four companies) and the associated prediction times. Accuracy was measured as the absolute value of the difference between the subject-predicted value and the model-predicted value.

In order to evaluate the data independently with respect to company and prediction time “distance”, the accuracy data was segmented by observation made by the subjects. Each subject made exactly one prediction for each time period for each company. A model of randomized blocks was developed. The mean for each block was calculated providing the model with one observation per cell. These data, in conjunction with Friedman’s Rank Sums Test, were used to test the first hypothesis. Friedman’s Test ($= 5.17$), using the representations as treatments, results in a p-value of .076. This provides some evidence that there are differences in the accuracy of predictions, based on the visual representation used to make those predictions. This evidence may be considered mild evidence with regard to rejecting a null hypothesis (Coakley, 1996). Next, the direction of the differences among the treatments was investigated. Page’s test (Page, 1963) for ordered alternatives in a two-way layout was used to test for the direction of the relationships. Page’s test ($= 155$) resulted with a range of p-values from 0.01 to 0.05. This suggests strong support for the order of accuracy of representations $R3 \leq R2 \leq R1$, where at least one of the inequalities is not a strict equality. Evidence from Page’s test and Friedman test supports the rejection of the null hypothesis (H1) and is consistent with the alternative that proposes increased accuracy of predictions using multi-dimensional representations of multi-dimensional data.

The second hypothesis suggests that an increase in the dimensionality of the representation should decrease the time required to make the prediction. Friedman’s test was executed on these samples, based on decision time, by representation treatment, blocked on the twelve predictions made by individuals. The results of the Friedman’s test ($= 15.5$) indicate strong support (p-value = 0.001) for the rejection of the hypothesis of no treatment differences with respect to prediction times. Again, Page’s test was used to test the order of differences. However, in this case, Page’s test ($= 129$) did not provide support for that order of differences. But, the strength of the results from Friedman’s Test indicates additional consideration of the cause of the differences may be warranted.

During the experiment, the researcher noted that subjects using R3 appeared to use a significant amount of time rotating the image and observing the graphic from multiple viewpoints. Based on this observation, a high level analysis of the audio tapes recorded during the experiment was performed. By listening to a small random sample of the tapes, the experimenter verified that subjects given the rotatable image appeared to rotate the image multiple times prior to making their predictions. Comments, other than those relating to the rotation, were similar among the groups. This led to the conclusion that if rotation of the image is required to understand the relationships among the data, the rotation process and the mental adjustment to the new viewpoint may increase the total time to make a decision. Based on this insight, Page’s test was run again with the order changed to indicate the times required for the decision process ($R1 \leq R2 \leq R3$.) This time, Page’s test ($= 159$) strongly support this new direction with a range of p-values from 0.001 to 0.01. With regard to this new hypothesis, there is evidence that prediction time differences result from the different treatments, but the differences are in the opposite direction from the initial hypothesis of this research.

Summary

The results of this study indicate that the form of the representation of data affects the accuracy of predictions based on that data. Although the decision accuracy was improved by using the 3-D formats, the results do not indicate that in this instance, decision-makers use less time in forming their conclusions when using higher-dimension representations. In fact, increased complexity may add time to the decision-maker's interpretation time. From a practical point of view, this study indicates that one should consider the interpretation time factor when designing and developing visualizations.

Regardless of the type of problem to be solved, when developing visualizations a question regarding the appropriateness of the data presentation always exists (Vessey 1991, Lohse, Biolsi, Walker & Rueter, 1994). Additionally, previous research has demonstrated differences among individuals, based on their visualization abilities (Marks 1977). Future research should include the adaptation of measures of these differences.

Visual representations are available upon request (rdull@iupui.edu; dtegarde@vt.edu).

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