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ABSTRACT

Data flow diagrams (DFDs) are commonly used models for representing business processes. The traditional presentation of DFDs provides separate views of major system processes from views of their subprocesses. This separates the details of the low-level system activities from their context. Although this separation can reduce information overload, it can degrade the viewers' understanding of the overall system. Fisheye views are one method of information presentation that emphasizes local detail while providing overall context clues, and are used in different contexts to alleviate such degradation effects.

In this research (in progress), we investigate the application of fisheye views to the presentation of DFDs. We propose that the fisheye representations will more successfully communicate the information to its viewers than a series of separate diagrams. Through a controlled experiment, we will collect data in order to test the validity of this proposition.

1. INTRODUCTION

1.1 Process modeling and DFDs

Systems analysis is defined as the activity of understanding complex systems (Hicks 1993). Identifying, describing, and modeling business processes – those activities in a firm that create value (Alter 2002) – is a key part of obtaining that understanding. Business processes, defined by Davenport

(1990) as "a set of logically related tasks performed to achieve a desired business outcome," are the building blocks of a business system. Once these business processes are understood, information technology can be used to support them through system design and implementation, or the processes can be improved or radically redesigned (called Business Process Reengineering) in order to improve productivity (Davenport 1990; Hammer 1990).

A Data Flow Diagram (DFD) is a commonly used tool to represent an organization's business processes. A diagrammatic representation such as this gives a comprehensive and relatively easy method for understanding how the business or organization works for both the technical system analyst and the non-technical business manager. As stated by Hahn and Kim (1999), a "well represented" diagram is one that "supports the cognitive processes effectively in reasoning with the diagram." Furthermore, research has shown that even in manufacturing organizations, information makes up 80% of the flows between processes (Kock and McQueen 1996). It is reasonable to assume that this percentage would be even higher in service-oriented industries. It is for this reason that process redesign approaches that focus on information flow "will be preferred by practitioners over those based on the traditional activity-flow view of processes." (Kock 2001) Other methods of diagrammatic representation in systems analysis and design, while popular, do not focus on the flow of information within and between business processes. For example, the Unified Modeling Language (UML) is often used in object-oriented development, but focuses on activity flows between "actors," not the flow of information. Flowcharts, like UML-based models, are primarily used to represent activity flows instead of data flows (without an "object-oriented" perspective of these activity flows). Therefore, the Data Flow Diagram remains an effective method of representing business processes since it is the dominant method of diagrammatically representing information flows in a business system.

There are four components to a DFD – processes, data flows, data stores, and external entities. Together, these elements create a map of the processes within a business. Because business processes can often be complex, involving many data flows between multiple processes, entities, and data stores, the corresponding DFD can also become complex. The literature in psychology suggests that human capacity for processing multiple pieces of information is limited (Miller 1956, Mandler 1967). Therefore, an effort to simultaneously explore all relevant business processes in detail would create an excessive amount of information that cannot be processed easily. Such excessive demand for information comprehension beyond the cognitive capacity of an information user is referred to as "information overload."

To avoid information overload, DFDs are simplified by splitting the representations into different levels, depending on the degree of detail. A context diagram shows the entire system in the context of the organization. A Level 0 diagram contains elements describing the major subprocesses of the system. A series of Level 1 diagrams contain further detail regarding each subprocess of the Level 0 diagram. For DFDs representing large-scale systems, there can be a large number of levels. It is left to the viewers of these diagrams to integrate context and details in their minds while switching back and forth between different levels. Such integration is not always easy, and often causes disorientation problems where viewers feel lost within the complexity of the hierarchy. System analysts are therefore faced with a dilemma regarding the level of detail in representing businesses processes. One option, the creation of a comprehensive diagram, could cause information overload. The other option, the creation of a series of diagrams representing different parts of the overall system, may cause people to "get lost" while trying to switch between diagrams containing different levels of detail. The presentation of DFDs would be more effective if the diagrams at different levels of detail could be organized and presented in a way to smoothly integrate context and details. Below, we propose one such alternative method of presenting DFDs that is both comprehensive and easily understandable.

1.2 Fisheye Views as a Possible Solution

Psychology's gestalt theory deals with issues regarding details and context, stating that details have more meaning when presented within their context. Specifically, Wertheimer states, "there are wholes, the behavior of which is not determined by that of their individual elements, but where the part-processes are themselves determined by the intrinsic nature of the whole." (Ellis, 1967) According to Furnas (1986), an efficient way of embedding a specific piece of information within its larger context is to represent those portions of the context that are closer to the immediate area of interest in greater detail while including only some major landmarks of the context further away. "This suggests that such views ('fisheye views') might be useful for the computer display of large information structures like programs, data bases, online text, etc." (Furnas 1986)

Since their introduction in 1986, fisheye views have had various applications, such as the display of information structures as hierarchical tables (Egan et al. 1989), computer graphs (Sarkar and Brown 1992), and hypertext (Bederson et al. 1998). Some of the application domains have been groupware (Gutwin and Greenberg 1997) and monitoring systems (Schafer et al. 1998). Schafer et al. (1998) and Leung and Apparley (1994) present summaries of selected fisheye visualization systems and their enabling methods.

The concept and applications of fisheye views are promising in integrating context and details in a smooth way to facilitate better understanding. We believe that the hierarchical structure inherent in a set of DFDs used to model business processes makes these diagrams an appropriate application for fisheye zooming. Such an application would make it possible to see different levels of business processes simultaneously with an overall view of the system. This leads to the following research question:

Can the presentation of DFDs through fisheye views improve the understanding of the business processes that the DFDs represent?

1.3 Organization of the paper

In the next section, the basis of our motivation to pursue the answer to our research question is reinforced through a review of theory that suggests that such an approach would indeed be effective. We also review fisheye zooming systems that have successfully implemented the idea in various application domains. In the third section, our research methodology is discussed. This includes a discussion of the design of the interface developed to conduct the experiment, the generation of the hypotheses to be tested, the design of the experiment itself, and the method of data analysis. Finally, the fourth section discusses the potential contributions of this project.

2. PREVIOUS RESEARCH AND IMPLICATIONS

2.1 The role of context in understanding details

Gestalt theory asserts that components have more meaning when considered within their context. In other words, the understanding of details is enhanced when considered along with the system in which they exist. Gestalt theory treats "the organism as a part in a larger field [that] necessitates the reformulation of the problem as to the relation between organization and environment." (Wertheimer 1924) This theory has implications for and has been applied to the domain of information systems, both in systems analysis and design as a whole and specifically in the diagrammatic representation of information. Gottschalk (1997) stated that a gestalt approach to information systems planning is essential, and it would include consideration of the "complete picture that can be [is] largely ignored in the planning of individual systems." Similarly, according to Finnegan et al. (1999), the study of how humans perceive and group information by assigning it value relative to other information presented in the same field of view is extremely important.

2.2 Fisheye views

Furnas was one of the first researchers who studied the perceptions discussed in the above section as they apply to graphical interface design. In the original paper by Furnas (1986), in addition to the description of the basic motivation for fisheye views, the "degree of interest (DOI) functions" concept was introduced to formalize generalized fisheye views. According to this formulation:

$$DOI_{fisheye}(x,y) = API(x) - D(x,y) \qquad \text{(Eqn 1)}$$

where $DOI_{fisheye}$ is the user's degree of interest in a given point x given that the user's point of focus is y,

$API(x)$ is the given a priori importance of x, and

$D(x,y)$ is the distance between x and the current point y.

Using variants of this formulation, fisheye views could be defined in a number of different structures (Leung and Apparley 1994). Furnas demonstrated an application for tree structures and tree-structured text files. Sarkar and Brown (1992) used a similar formulation, and applied the fisheye view technique for viewing and browsing computer graphs. They built a framework to incorporate arbitrary structures by redefining the concept of "distance."

An interesting application of the fisheye view idea comes from Collaud et al. (1995). They introduced their CZWeb tool that makes use of two techniques – fisheye views and continuous zoom – to help users navigate the web. The prototype graphically displays a network in a rectangular 2-D display space. A hierarchy is used to display some web pages in great detail and the others in less detail or no detail at all. This study is important in that it was one of the first attempts to apply the fisheye view technique to a very appropriate domain.

In another study, Bederson et al. (1998) report on the development of a Web-browsing prototype in Pad++, a multiscale graphical environment. This prototype displays multiple Web pages and the links between them instead of showing one page at a time. A fisheye view approach is used in this display method where the page in focus is clearly readable whereas the others are shown in smaller scales to provide context. This approach was compared to the traditional display method of Netscape in several different scenarios, and the authors found that after some changes to the prototype, subjects using Pad++ answered questions 23% faster than those using Netscape.

Lamping and Rao (1996) describe an implementation for presenting a 2-D graph through a fisheye zoom. The hyperbolic browser provides a smoothly varying "focus plus context" view where the display space allocated to a node decreases continuously with the distance from the focus, yet does not disappear abruptly. Display of a specific node in the graph within the context of the other nodes is shown in Figure 1. Figure 2 shows the effect of carrying a node to the focus. This application of fisheye zooming is one of the best known and successfully commercialized (Hyperbolic tree form Inxight®, Hane 2000). The integration of details within context by means of a spherical distortion proves to be a good way of looking at those details without losing awareness of the overall picture.

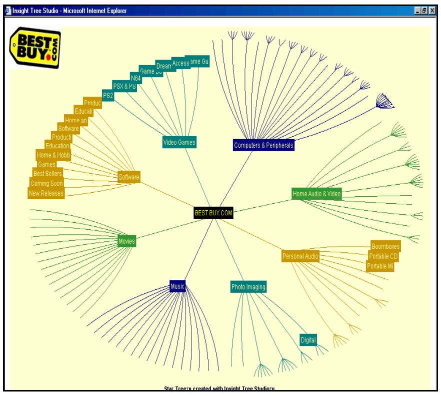

Figure 1: An organization chart

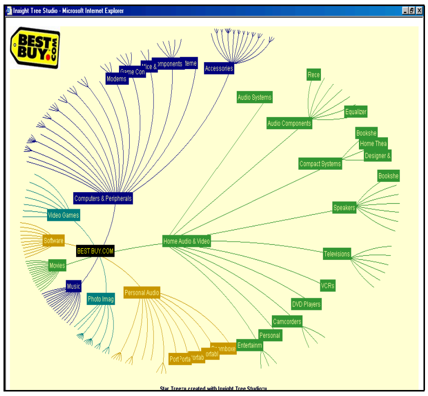

Figure 2: Changing focus on the organization chart in Figure 1

As evident from the brief discussion in this section, fisheye view systems have found applicability in information visualization especially in the visualizations of complex spaces. The idea to smoothly integrate the context and details is promising, but needs to be modified for specific implementations. Because of the hierarchical structure of DFD representations and the related problems, fisheye views of DFDs may be more successful representations than the traditional views. Our implementation of the fisheye technique is a modification of the original design principle shown by means of the examples covered here.

An important observation in this review shared by other comprehensive reviews (for example, Leung and Apparley 1994) is that most fisheye view systems developed so far have not been tested in rigorous usability studies. Accordingly, not much is known about their actual usefulness in spite of their conceptual appeal. Our study is one of the relatively few efforts to not only propose a creative design for the user interface of a commonly used system analysis model, the DFD, but also to find empirical evidence for the success of the proposed representation ideas. Therefore, we believe that the contribution of the research is significant.

3. RESEARCH METHODOLOGY

3.1 Interface development

In order to implement the design ideas discussed in the previous section, we have developed an HTML-based navigation tool. The tool is used to display a complete DFD for a hypothetical business. In order to compare the success of fisheye representations of DFDs to that of standard context-free diagrams, two sets of diagrams are created. One set has each separate subprocess DFD in its own diagram, without any information about its context within the rest of the system (the levels that are higher in the hierarchy). The second set has each separate subprocess DFD in a fisheye diagram, which also includes contextual information from the higher levels.

The starting point for the user of the system is a Level 0 diagram (see Figure 3). This diagram is a “clickable” hypertext page. Clicking on a subprocess takes the user to the DFD for that subprocess (Level 1 diagram). Depending on which version of the tool is used, the DFD that the user sees is either the standard (see Figure 4) or the fisheye diagram (see Figure 5). The user can navigate between the diagrams through the tool’s interface. The fisheye version of the DFD incorporates emphasis on the Level 1 subprocess detail along with its context. The elements containing information about the subprocess are larger than the elements of the rest of the diagram. In other words, context information is included in the diagram but is smaller in size than the details.

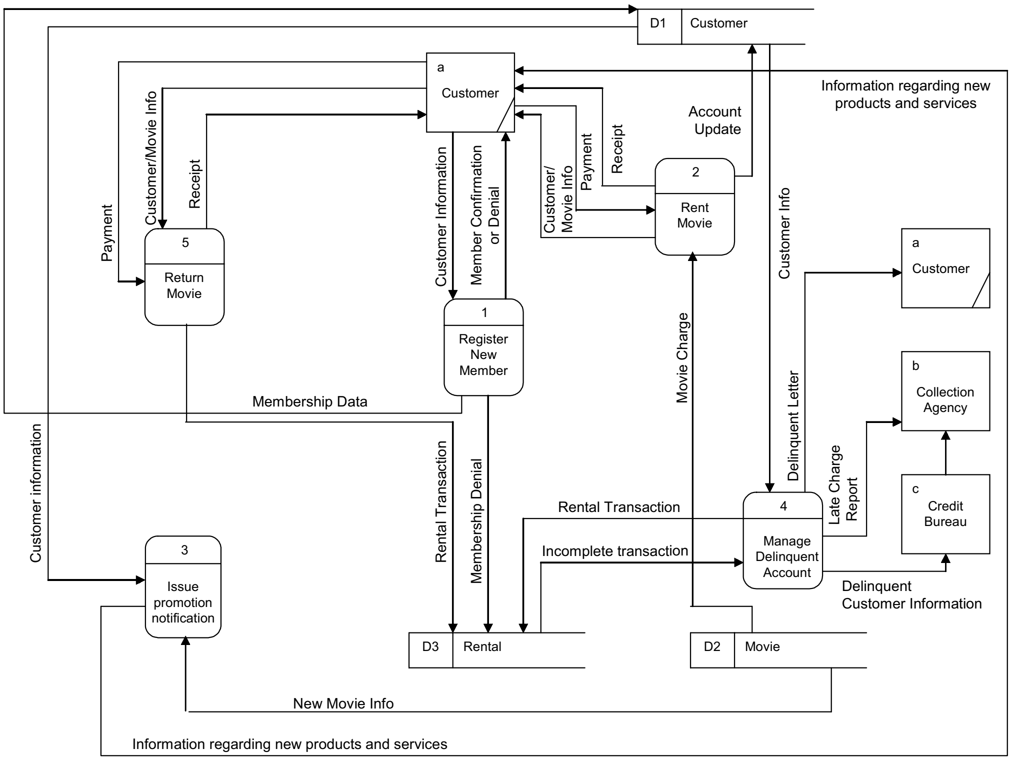

Figure 3 : The level-0 diagram

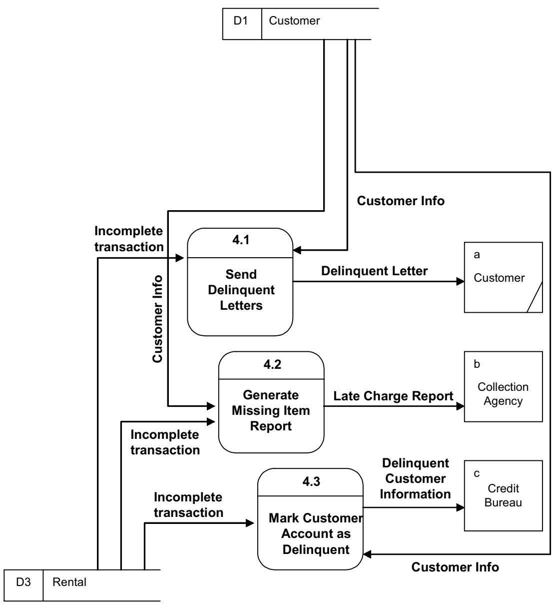

Figure 4. Viewing the details of process 4 separately from the context

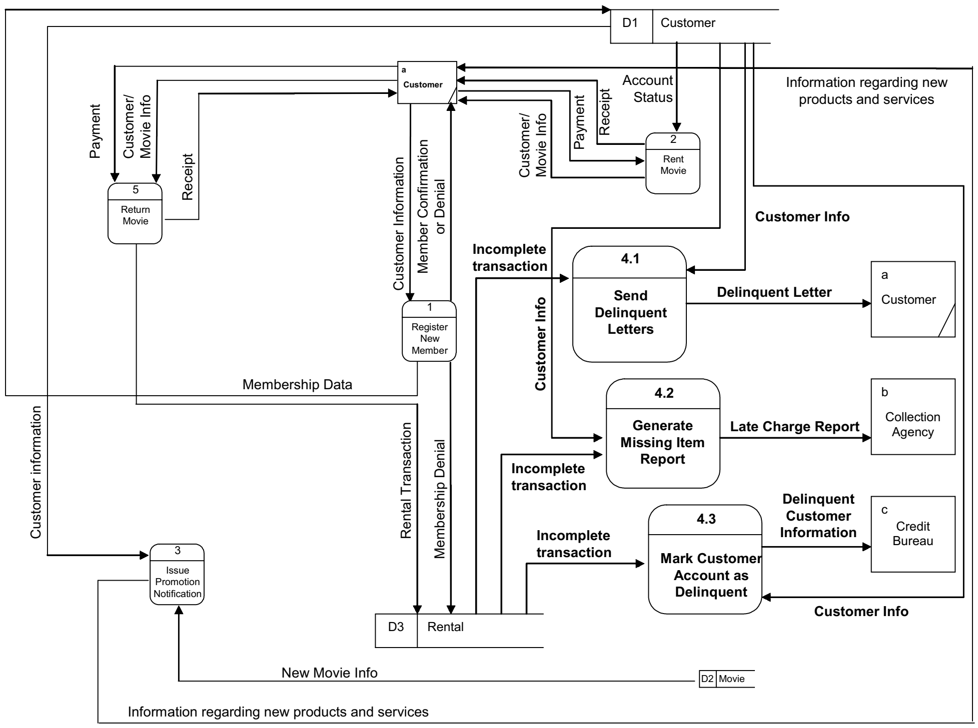

Figure 5. Viewing the details of process 4 by means of a fisheye view

In standard Data Flow Diagrams, the distance between elements has no particular significance. Accordingly, the fisheye representations of DFDs cannot be based on standard distance measures. However, we know that the elements that are at the same level of a DFD are more closely associated with each other than with elements at a different level (more data flows are exchanged between elements at the same level). This degree of association is used to represent the Degree of Interest in two ways. First, elements that are part of the process that is the subject of the focus are placed close together, and elements that are not "in focus" (the "context") are placed further away. Second, elements that are part of the focus are relatively larger compared to the elements that are not part of the focus.

3.2 Hypotheses

We believe that the fisheye visualizations of the DFDs as described in the previous section will result in a better and quicker understanding of the business processes. Accordingly, subjects will be more successful in identifying how the processes can be modified or improved. To test this, we present the subjects with different diagrammatic representations of the business processes, and then ask them to modify the processes to implement predetermined changes to the system. The subjects' responses will be evaluated by a number of system analysis and BPR experts. The rating of the quality of the subjects' answers by the experts will serve as a surrogate for the level of understanding. The success of a presentation system in improving understanding should also be reflected in the speed that the subjects arrive at their answers. Therefore we will also measure the time it takes for the subjects to finish answering the set of questions. We formulate the following hypotheses from these operationalizations:

H1: Subjects who use the fisheye visualization will receive a higher score for the process modification task than those who use the traditional representation.

H2: Subjects who use the fisheye visualization will complete their task more quickly than those who use the traditional representation.

The main assumption in the operationalization of understanding is that without a good understanding of the current processes of a business, it is impossible to suggest changes that will improve them. This assumption may be problematic for two reasons. First, if subjects do not understand the basic DFD representation, then it will be impossible to identify the reason for their lack of success with the experimental task. Such a failure may be due to the specific form of representation used (the effect that we are interested in), or the fact that the subjects do not understand these representations in general. To reduce the chances of the latter happening, we will control for the subjects' previous experience with DFDs by selecting subjects with similar familiarity with DFDs. We will also conduct a pre-test to measure the subjects' competence in creating and interpreting DFDs.

Second, even with good understanding, some subjects may not be as successful as others because they are not knowledgeable or creative enough to suggest meaningful changes. We expect that random assignment of subjects to experimental groups will evenly distribute expertise (previous experience) with DFD models and aptitude with process improvement between the groups.

3.3 Experimental design, procedure, and data analysis

The subjects will be randomly assigned to two groups. Both groups will use a navigation tool that allows them to click on processes to explore them in more detail. The first group uses the version of the tool that contains separate views of the DFDs. The second group uses the version that contains a diagram that displays varying fisheye representations depending on the area of zoom. The answers the subjects provide, along with the time it takes the subjects to answer the questions, will be recorded.

In the analysis, demographic information and cognitive style will be controlled for. This information is collected as part of the experimental procedure. The demographic information includes age, gender, native language, and prior experience with DFDs. Cognitive style is measured using the Embedded Figures Test (Witkin et. al., 1971).

After verifying the basic Analysis of Variance (ANOVA) assumptions, we will perform a multivariate analysis of variance (MANOVA) with the assessed quality of subjects' responses and their speed of completion as dependent variables. Method of presentation will be the independent variable, and cognitive style and demographic information will be used as control variables. A MANOVA is appropriate because we believe that the dependent variable measures will be correlated. If we find that a significant correlation does not exist, we will perform two separate ANOVAs. On the other hand, if the basic ANOVA assumptions cannot be verified, the data can be analyzed using nonparametric tests.

4. CONTRIBUTION

There are two major potential contributions of this research. First, for academics, the application of fisheye views to the creation of Data Flow Diagrams offer a novel approach to representing business processes models. We believe that the introduction of our heuristics is a good start, and would stimulate further research into improving how such applications should be created. Second, for practitioners, our empirical study that tests the usefulness of this application clarifies whether it is worth spending effort in standardizing the creation of Fisheye Data Flow Diagrams and integrating such a technique into CASE tools and other development products.

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