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Gearing Up: Visualizing Decision Support for Manufacturing

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Introduction

Computer-based decision support systems (DSS) are defined as systems that have been designed to support and improve human decision making. According to Keen,[1] some researchers define DSS simply as an interactive system for use by managers, some focus on DSS as a support in the decision process, and others focus on DSS as a way to access analytic models.

Decision support systems come in many shapes and sizes depending on the context of their implementation—the scale and complexity of the domain, organization, and/or the decision making process. One basic example of DSS use would be an online book seller wanting to determine whether selling his products internationally would be a wise business decision. A DSS could collect, analyze, and present data from internal and external sources in order to help the seller determine if there is demand for such an expansion, and if the company has the ability or potential ability to expand its business. In a more complex example, a DSS could be developed for plant-wide decision making, with a view of improving knowledge of the global impact of individual decisions. For example, what is the impact on water, gas, and oil consumption if ten more delivery trucks are added to the system?

Theoretical possibilities exist of building a DSS in any knowledge domain; notable work has taken place in business, medicine, defense, manufacturing, transportation, forestry, and law. Once implemented, a decision support system has to meet the needs of different types of users, depending on its intended sector. A military decision structure, for example, will be fundamentally different from a business decision structure, and the decision makers will vary in terms of their needs, expertise, strategies for knowledge management, and managerial hierarchy.

Our project deals with DSS design for an ice-cream manufacturing operation. Ice-cream manufacturing is a useful example because it is a multi-modal system that contains sufficient complexity in the processes to be generalized to many other kinds of operations. For manufacturing operations, DSS users will vary in terms of their placement along the managerial structure; some may only have access to their particular domain and relevant decisions, while others may have access to a large portion of—or even the entire—system. Visitors may be invited to view parts of the system, in which case certain processes and/or decisions may need to become hidden from view.

This project is a continuation and expansion of a previous project entitled "Optimization-based Decision Support for Integrated Mining Operations," which focused primarily on:

- formulation of the truck allocation problem within the mine as a vector optimization problem;

[1] Keen 1978.

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- post-optimality analysis of such vector optimization problems, with a particular emphasis on stability of the Pareto set and members therein; and
- visual methods for exploring truck allocation problems for the surface mining application and presenting solutions to operations personnel.[2]

The current project builds on the framework and ideas developed during our prior work to create a proof-of-concept decision support system that is targeted at ensuring information is available to personnel making local operating decisions and the business-wide impacts of these decisions. In this paper, we provide some background to decision support system design, and then describe our recent designs for a new series of DSS visualizations.

DSS Design

Over the last thirty years a number of different approaches to DSS have been developed and, during that time, each approach has had a period of popularity in both research and practice. These different approaches to decision support represent differences in the scope and scale of project, potential impact on the organization, type of technology, and managerial structure:

- personal decision support systems;
- group support systems;
- negotiation support systems;
- intelligent decision support systems;
- executive information systems and business intelligence; and
- knowledge management-based DSS.

Our project is an amalgam of several of the system types mentioned above. It is a group support system since responsibility for decisions will be shared by a number of managers and a number of managers will need to be involved in the decision process. It is also a knowledge management-based DSS, offering knowledge storage, retrieval, transfer and application to support the use of individual and organizational memory in decision making.

Generally, the output from decision support systems is displayed to the decision-maker using graphics whose origins date back more than three decades, even though important theoretical work on interface design for decision support has taken place. One of the basic requirements for these interfaces is that they will translate the data and related decision support calculations into forms that are accessible to operators who may not have a background or training in engineering math. The use of visual representations in place of numbers is therefore a priority. The visual interface plays an important role in supporting the decision maker and, according to Yu, should allow users the following actions:[3]

- generate and submit requests for information and decisions;
- browse retrieved information, including the computational results of decision models;
- revise inputs and activate "what if" analysis;
- give and receive feedback with respect to system outcomes and performances;
- select and execute applications and functions; and
- log into and log out of the application.

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[2] Ta et al. 2005.

[3] Yu 2004.

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An effective visual interface may help increase a decision maker's effectiveness: extending his or her knowledge of the decision-related environment by, for example, automating clerical tasks, expediting problem solving, facilitating interpersonal communication, fostering organizational and personal learning, and/ or increasing overall organizational control. Miner et al. describe several desirable characteristics of decision support systems–all with the goal of supporting the user throughout the decision making process. These characteristics are fundamental to a successful interface design:[4]

- *Conversational and interactive:* users can interact with the system using English-like commands.
- *Flexible:* users can combine different modules or segments of the system to solve a problem.
- *Adaptable:* the system is changeable according to the user's needs and capabilities.
- *Helpful:* the system should be simple and forgiving.
- *Quick:* the system should be responsive and timely.
- *Reliable:* the system should be reliable and give correct answers.

Our Interface

Our previous study[5] had shown that decisions in various environments were routinely connected to the time of day, as well as the calendar. We also identified several types of information that our earlier designs (Figure 1) had not supported. These include the interconnections between different decision factors and the thresholds at which they would be active. We also had to accommodate different types of variables, where some (such as flow of water) are continuous and others (such as containers) are discrete.

[4] Miner et al. 1981.

[5] Paredes-Olea et al. 2008

Figure 1. An earlier phase of this project provided a system for experimenting with decisions, based on the flower diagrams used by Florence Nightingale in reporting causes of death in the Crimean war. *(Design by Carlos Fiorentino.)*

We produced a working space consisting of a revision of Bradford Paley's TextArc Calendar (2007), where a circle represents the time and date and the interior space is available for visualizing the factors in a decision at any given time (Figure 2). Time has implications not only for decisions at a given moment, but also in the context of long-term use, where parts could wear out, or some components of the process (e.g. warehouse pallets) are available for reuse, while other components (e.g. eggshells) are used only one time and then discarded.

Within this interior space, we provide a variety of sprocket-like objects that can be directly manipulated by the user[6] while they are in the process of addressing a particular decision. We have been developing a set of rich prospect browsing principles to help inform the design of new affordances in interfaces to digital collections of documents. Our sprockets enable digital affordances, which is to say, opportunities for actions, to take place.[7]

[6] Shneiderman and Plaisant 2004

[7] Gibson 1979; Vicente 2002.

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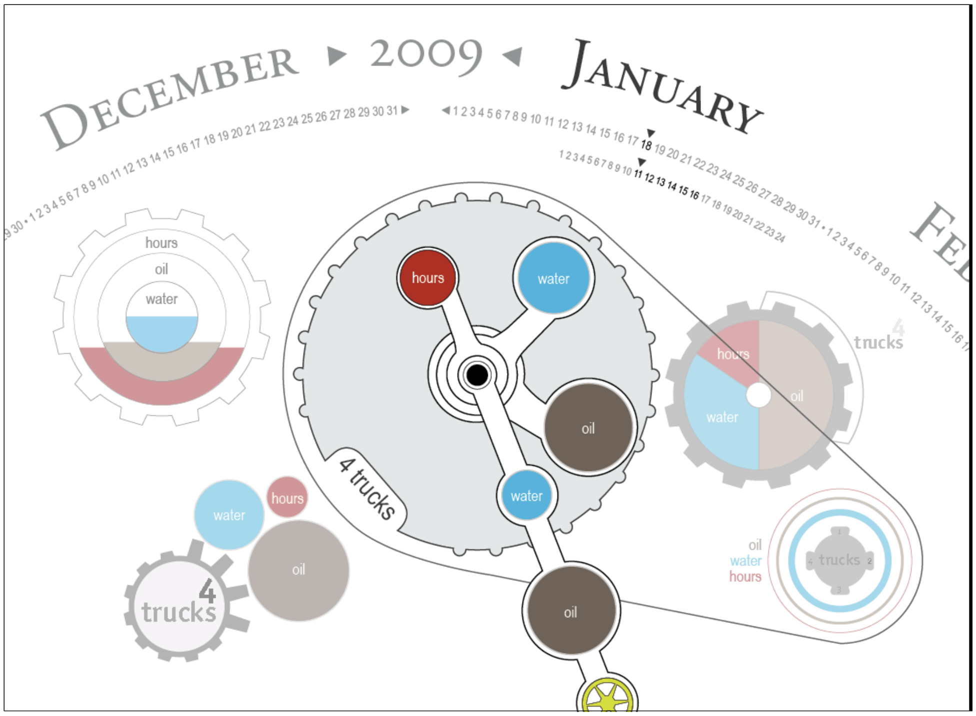

Figure 2. Our new design is framed using a circle that indicates time and date, while the central space is occupied by sprockets that support direct manipulation. This design allows the user to interactively adjust variables and view the outcomes and effects of their decisions.

So far, we have identified six core affordances for the sprockets:

- *Experimenting with different decisions:* our sprockets enable the user to compare multiple decisions that have been made in the past and experiment with different decision scenarios;
- *Choosing a starting point:* the user can choose a decision, a variable, or time/date as a starting point for experimenting with or reviewing decision;
- *Displaying and managing decision variables:* the interface presents a prospect view of the decision space which can be organized by either time/date or type of decision;
- *Recognizing different variable types:* we have began to create a system of sprocket design that uses the size, amount, shape, transparency, and colour to represent the type of decision being made and the nature of individual variables;
- *Connecting decisions to time:* the user can select days/hours as a sequence or independently, display a micro and/or a macro system view, and review past, present, and future (experimental) decisions;
- *Tracking consequences:* the user can review the impact of previous decisions on stages of operation and consequences of inaction.

We have also considered additional affordances for the system overall:

- *File export:* decision experiments, implemented decisions, and/or decision outcomes may need to be exported for use in other systems;
- *Decision reporting:* a decision summary based on date range, decision type, or manufacturing cycle may need to be generated; a playback function may be useful for training purposes; reporting should support numeric values and visuals;

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- *Access control and collaboration:* some decisions may depend on one user's input, while other decisions may require cross-departmental or even cross-site collaboration; multiple work areas may be required to control the type of information displayed to visitors or trainees, for example, versus plant managers.

The manufacturing process can be viewed as a whole or as a series of interrelated parts. Decisions made on one part of the process are often affected by and, in turn, influence numerous other processes. In addition, a decision can spur the need for decision making in other parts of the system. For example, consider the scenario of a manager alerted to a 30% drop in the price of milk (Figure 3). Before she can make the decision as to whether to buy milk at the reduced price (and how much milk to buy), she must consider several factors:

- *Storage:* is there enough cold storage to accommodate a milk purchase; if there's an increase in ice cream production, can it be stored if needed;
- *Production increase:* will she need to increase production to make use of the additional milk; is there enough of the other ingredients to increase ice cream production;
- *Packaging:* is there enough packaging or packaging materials to accommodate an increase in production;
- *Shipping:* can shipping handle an increase in production;
- *Waste:* will there be an increase in waste; how much waste is too much;

While considering the milk purchase, the manager may also find it useful to review current milk levels, as well as the outcomes of similar, past decisions.

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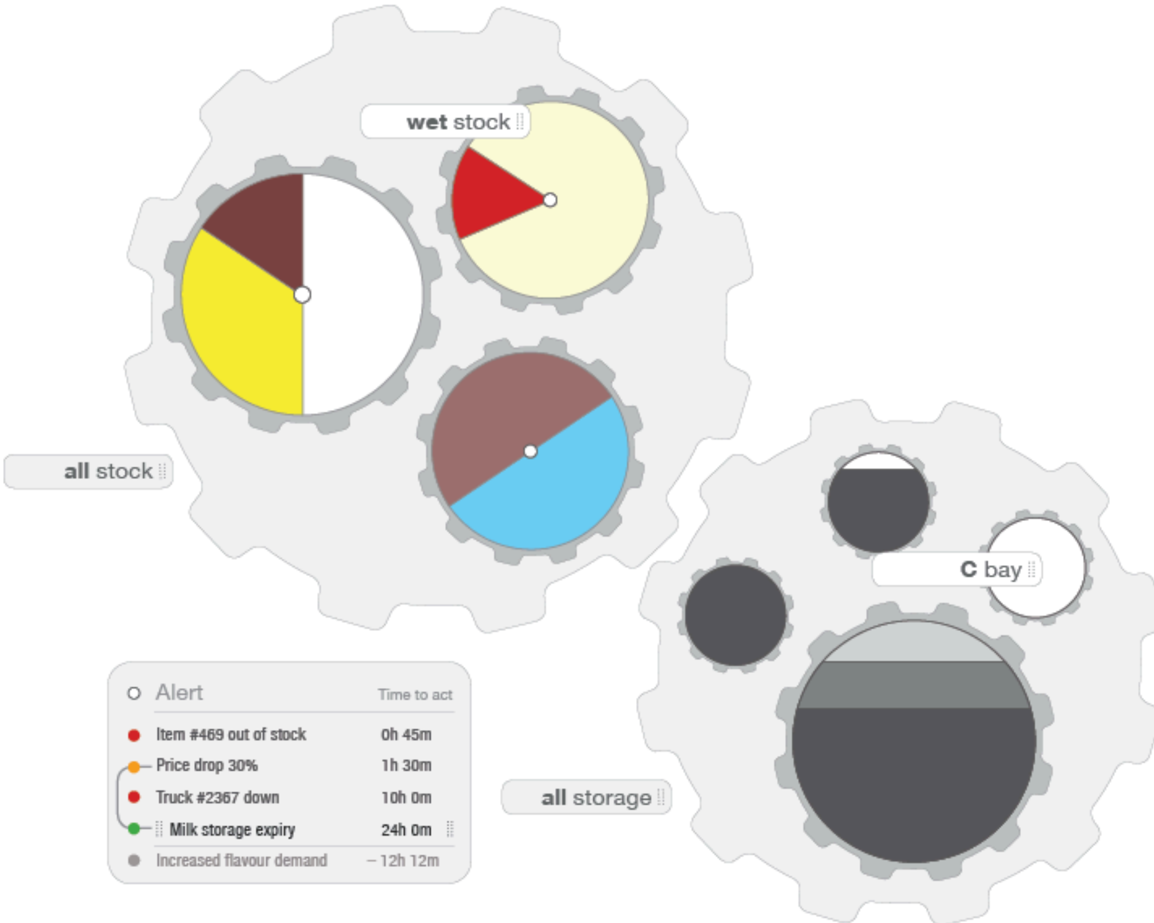

Figure 3. An alert may be one of the starting points for initiating a decision. Depending on the type of alert it is, the user may choose to display a small component of the overall system—stock levels, for example—as well as any other, related components—for example, current storage usage.

Conclusion

We have yet to address the connection between the system and its trigger for action. That is, the system helps to support scenarios for decision, but does not necessarily connect directly to the system where the decision is enacted. We also need to visually distinguish between inputs to the system and outputs, and also indicate the scope of the decision in terms of its possible consequences.

We also need to develop a strategy for providing clear means for comparing different kinds of decisions, since it may not always be obvious which decision is optimal. In addition, we need to create a visual (and, perhaps, auditory) system for different types of system alerts. Finally, this project provides the opportunity to examine how decision support systems should be implemented to ensure fault tolerance. When a decision-making node (i.e., a local decision-maker) is unavailable, or a portion of the decision-making system fails, the remainder of the decision support system

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should be tolerant to this failure and continue to provide valuable information to the remaining nodes within the scope of the decision support system.

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