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A Framework for Situated Decision Support Systems

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Abstract

Internet facilitates easy access to data, information, and knowledge sources available online. This provides an unprecedented opportunity to empower decision support systems with capabilities of directly accessing problem environment and implementing decisions while effectively combining higher degree of automation with human judgment. The central argument of this work is that in dynamic electronic environments decision support systems should be situated in the problem environment. A generic architecture, the set of capabilities for our vision of a situated DSS is proposed, and the architecture is illustrated using a DSS for investment management.

1. INTRODUCTION

During the past thirty years since the conception of DSSs the business environment has changed in several ways. The most significant changes include:

- Globalization of economy and the growing complexity of economic relationships;
- Flattening of organizations and growing employee empowerment;
- Increasing need for fast response in the dynamic competitive environment;
- Explosion of information accessible through electronic networks;
- Emergence and growth of electronic commerce; and
- Better-informed and empowered customers.

In light of these trends the classical "problem-solving" characterization of DSSs needs to be expanded and integrated with the growing interconnectedness of the business environment. The traditional "isolated DSS" view hampers their usefulness for today's decision makers and is incompatible with such new information technologies as enterprise resource planning, supply chain management and customer relationship management. DSSs need to be seamlessly integrated in the firm's information environment. They also need to empower users by providing them with relevant information, informing decision-making process, responding to the emerging situation, and being capable to influence the environment in the desired direction.

The main purpose of this paper is to lay a foundation for a new generation of decision support systems, the situated DSSs (Vahidov and Kersten 2002), which we refer to as a *decision station*, and propose a model and architecture for these systems. We view such DSSs as being active and closely linked to their respective problem environments. The paper presents architecture for a decision station based on agent components and provides an illustration of the proposed new generation of DSSs.

2. THE CHANGING ROLE OF DECISION SUPPORT

2.1 Situating DSSs

Effective linking of DSSs to their problem environments would enable improvement of strategic capabilities of organizations through timely response to the dynamically arising challenges through combining high level decision-making with automation and IS support of various business operations. The requirement of the DSS connectedness to its environment builds upon the concept of an active DSS (Angehrn 1993; Raghavan 1991). The advocates of active DSS point out the weakness of traditional support for being passive, where the user has to have full knowledge of system capabilities and exercise initiative in performing decision related tasks.

While activeness is argued to be a desired feature of DSS, the question of synthesizing active DSS and decision makers still remains unresolved. The complexity of a powerful DSS is one of the key barriers to its effective use by decision makers (Carlsson and Turban 2002). This is especially true due to the advance of relatively new technologies, such as neural networks, genetic algorithms, and others (Dhar and Stein 1997; Fazlollahi and Vahidov 2001). In our view, there is a need for an additional layer between DSS and the user that would fit the decision making needs of the user on one hand and the technical capabilities of the toolbox on the other hand. Such a layer would help shift the DSS view from technocratic to the managerial one.

To summarize we have argued that DSSs in modern era should be: directly connected to the problem domain/business environment, i.e. situated in that environment; be active participants in the decision process; and provide intermediation organized around human decision processes.

2.2 Insights from the Software Agent Research

Software agents are often characterized as proactive, reactive, socially able, intelligent, and purposeful entities (Franklin and Graesser 1997). Agents are situated in their environment; they are capable of sensing the state of the environment (e.g. load in electrical power grids, presence of e-mail messages in one's mailbox), and affecting that state (e.g. switching power lines, sorting e-mail messages) (Jennings 2000).

The developments in the software agents arena signify recent trends towards the adoption of the "situated" view. The relationships between expert systems, agents, and DSS are presented in Table 1. Situating DSSs within problem environments, providing them with capabilities to seek and sense the relevant data, and giving them ability to change the environment can bring about the type of support that today's organizations need.

Table 1. Comparison of DSS, expert systems, and intelligent agents

	Decision support	Artificial intelligence
Traditional	DSS	Expert systems
Situated	Situated DSS	Intelligent agents

Figure 1 gives a bird's-view of our perspective of new DSS as it relates to its users and the environment. With the increased need for tighter integration of DSS with users and the business environments, the additional wrapping layer is envisaged to encapsulate the toolbox-like DSS. On the user side the deciding, mediating and intermediating layers are components of the active interfaces. They conduct the dialog with the users to support their decision-making activities and utilize the DSS kernel capabilities as needed. In a nutshell, this layer will help the user learn more about situation, propose diverse alternative courses of actions, and provide quantitative and qualitative feedback on the alternatives to support decision maker's judgment. On the environment side, the layer will provide possibly advanced sensing and affecting capabilities to "situate" the DSS in the problem environment. We propose use of agent technology as the basis for building such DSS.

The goal of a situated, connected and active DSS is to provide all services necessary for decision-making and implementation. To reflect the comprehensive nature of such a system and also its integration with other systems and with the environment we call it a *decision station* (DS).

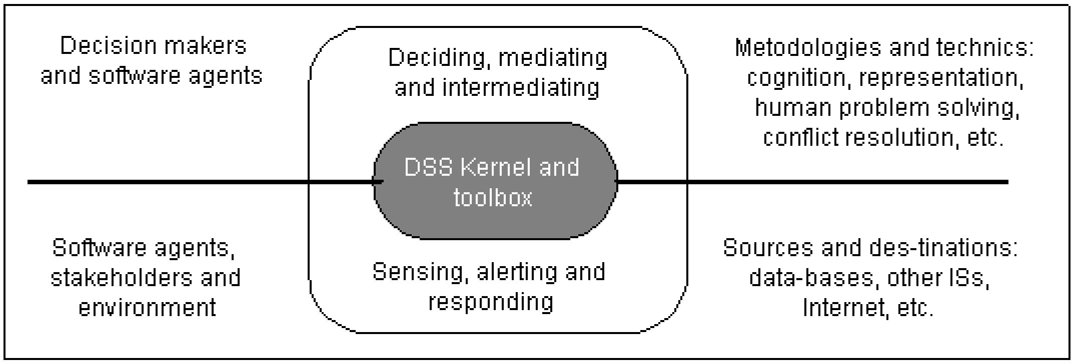

Figure 1. Enwrapped DSS

3. DECISION STATION

3.1 Generic architecture

Situating the DSS necessitates the addition of at least two key capabilities: (i) accessing the state of affairs, and (ii) changing the state of affairs. The former is achieved with sensors and the latter with effectors. Sensors, effectors, kernel, and active user interface comprise generic DS depicted in Figure 2.

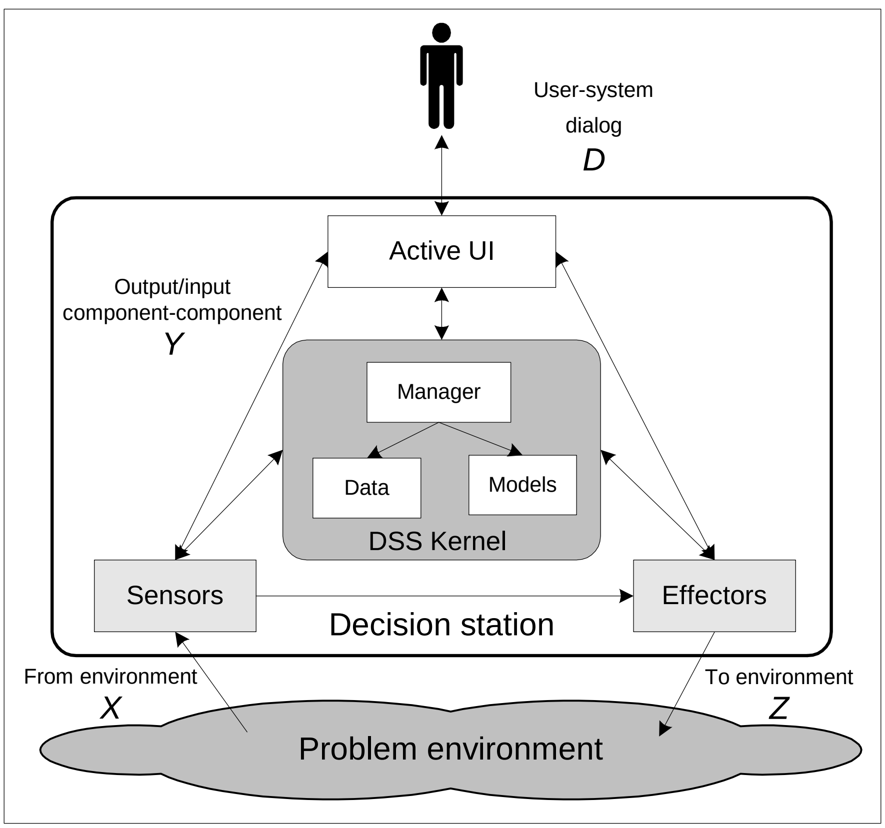

Figure 2. Generic architecture for a decision station

The *kernel* is composed of the DSS facilities in a traditional sense (i.e. database, models, and knowledge base). It includes an active component: the DSS *Manager*. The inclusion of the Manager reflects the view that the situated DSS needs to be capable of performing certain tasks autonomously, for example, contacting the user, preparing the system for interaction prior the user's request, and even making decisions when the user cannot be contacted.

Sensors capture the data relevant to problem domain from a variety of sources. The sensors however, should not be thought of only as mere means of capturing the data. They may incorporate more advanced functions as well, i.e. search for relevant sources, filtering and pre-processing of data, alerting generation and other useful features. *Effectors* are the devices used by a decision station to send signals to the problem environment with the purpose of directly altering current state of affairs. The effectors are not necessarily simple vehicles of decision execution or communication, but may engage in different activities required to implement a decision (e.g. converting the decision into more detailed plans, determining sequence of actions, and conducting negotiation in the course of implementing a decision).

Active user interface performs active support of the user's decision making process. One way to organize active interfaces is by Simon's human problem solving model. In this setup the active user interface contains intermediaries that specialize in supporting intelligence design, and choice phases of decision making. An architecture detailing such intermediaries is described elsewhere (Vahidov 2000). Since sensory and effectory capabilities are the key in enabling the situatedness of DSS we will discuss these in a somewhat greater detail here.

3.2 DSS sensors and Effectors

Sensors are used to access the state of affairs in the problem domain. In the trivial case, the sensors import relevant information into DSS. More advanced sensors need capabilities for locating, filtering and transforming relevant information, and generating alerts. With diminishing requirement of "switching media" when moving from decision-making to decision implementation, systems should enable implementation as well as monitoring of the results of decisions. Implementation primarily involves carrying out the decisions, but it may also entail planning and optimization activities, monitoring of execution, reviewing, and negotiating changes, if necessary. Conduct of these activities requires that the effectors have advanced capabilities. For example, production decisions may require purchase of items from suppliers with whom effectors could negotiate the purchase terms (Nissen 2000).

The examination of the basic capabilities of sensors and effectors reveals the fact that some of them are more "advanced" than the others. This insight leads to a dichotomous distinction between the "active" and "passive" capabilities of sensors and effectors. Table 3 summarizes passive vs. active capabilities of sensors and effectors

Table 3. Active vs. passive capabilities of sensors and effectors

	Sensors		**Effectors**	
	Capabilities	**Supported functions**	**Capabilities**	**Supported Functions**
Passive	Connecting	Importing data	Connecting	Exporting data, carrying out actions
	Transforming	Filtering, pre-processing, noise reduction, etc.	Transforming	Converting decisions into actions

	Alerting	Drawing user's attention, signaling to effectors	Querying	Requesting information or authorization from user or sensors
Active	Adapting	Search for new sources, attuning transformational and alert generation logic	Adapting	Identifying alternative destinations, Adjusting transformation and alerting logic, bidding tactics, etc.
	Planning	Determining order of actions, scheduling sensory (monitoring) and adapting actions	Planning	Determining order and scheduling of actions

4. DECISION STATION: AN ILLUSTRATIVE EXAMPLE

In this section we will describe an illustrative example of an agent-based investment Decision Station. The problem is in determining the portfolio of securities, monitoring its performance, and making modifications to the portfolio if necessary.

The sensors incorporate multiple agents that collect information from different sources. These include financial markets, historical information, analyst opinions, news articles, and other relevant sources. The sensors monitoring the markets collect information about overall market and specific industry performance indicators (S&P 500, DJIA, etc.), performance of individual securities from the user portfolio and the other securities on the "watch list".

The effectors are the means of executing the user's investment decisions. These can be linked to various online brokerage firms as alternative outlets for the ordering. The choice of the firm can be made interactively with the user on the basis of fees charged, reputation of the firm, past experiences, and other factors. The effectors support different types of order and can monitor execution of an order to see whether it had actually gone through or not. Active effectors can take charge of re-evaluating and resubmitting an order if necessary. Table 4 summarizes capabilities of sensors and effectors.

The DSS kernel incorporates the financial models for estimating portfolio risk and return, knowledge and formulas for conducting fundamental and technical analysis, and others. Manger decides when to update the local information, keeps track of performance of the models, translates user decisions into buy/sell signals for the effectors and may even authorize minor buying/selling decisions without user involvement within specified limits.

Table 3. Capabilities of sensors and effectors in an Investment Decision Station

Sensors		**Effectors**	
Capabilities	**Key functions**	**Capabilities**	**Supported Functions**
Connecting	Accessing stock quotes, market indicators (DJIA, S&P 500, NASDAQ), news articles, firms financial data, historical data, etc.	Connecting	Placing buy/sell orders, transferring funds between accounts

Transforming	Calculating moving averages, portfolio performances, speed of change in stock prices, market indexes, reconciling conflicting data, extracting keywords from news articles, etc.	Transforming	Calculating total amounts to be paid, placing special orders using pre-specified rules.
Alerting	Signaling a sharp change in stock prices, market conditions, notifying the user about key variables (price, P/E ratio, EPS) reaching pre-specified targets, signaling breaking news, etc.	Querying	Querying sensors about current prices to execute special orders, requesting for additional/missing information on order or seeking for confirmation of decision from the user, etc.
Adapting	Finding new sources of financial information, adjusting the thresholds for alert generation (e.g. in the case of sharp changes), assessing the credibility and reliability of sources to improve assessment of conflicting information, etc.	Adapting	Adjusting the rules for placing special orders, adjusting planning capabilities (below)
Planning	Deciding how frequently to read the stock, firm and market data, when to search for new sources, when to adjust alert thresholds, etc.	Planning	Deciding when to query the sensors, when to execute orders, etc.

The active interface adapts to the user preferences using direct and indirect input from the user. It displays the stock performance indicators and news articles that fit the user profile and interests. In an existing DSS prototype the system proactively generates four candidate portfolios (proposed by risky fundamental, risky technical, non-risky fundamental and non-risky technical analysis) for user's consideration. It also generates critique of the analyzed portfolios based on user profile. The described decision station will properly inform the investor about the situation, support his/her decision process, execute and monitor execution of the orders thus being an active situated system.

5. CONCLUSIONS

In this paper we have identified the need and conveyed our vision for a new type of Decision Support Systems. The distinguishing feature of such DSS is its situatedness in the environment. We have proposed a generic architecture for such system that included DSS kernel, sensors, effectors, and enhanced interfaces. Currently the work is underway to develop and evaluate prototypes for personal finance management and textbook selection. We hope to report some results at the conference.

In summary, we suggest that the increasing network connectivity in the world and the pressing need for effective decision support would drive the development and use of situated decision support systems.

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