Decision Station: A Notion for a Situated DSS

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Abstract

Despite the growing need for decision support in the digital age, there has not been an adequate increase of interest in research and development in Decision Support Systems (DSSs). In our view, the vision for a new type of DSS should provision a tighter integration with the problem domain, and include implementation phase in addition to the traditional intelligence, design, and choice phases. We argue that an adequate DSS in our dynamic electronic era should be situated in the problem environment. We propose a generic architecture for such a DSS incorporating sensors, effectors, and enhanced interfaces in addition to the traditional DSS kernel. We suggest the term “Decision Station” to refer to such situated DSS. We further elaborate on the possibilities to implement situated DSS in different segments of e-business. We argue in favor of using intelligent agents as the basis of new type of DSS. We further propose an architecture and describe a prototype for such DSS.

1. Introduction

Decision Support Systems (DSSs) as a field had appeared in the 70s and had enjoyed a steady growth through the 80s. the notion of a DSS as a problem solving, or “mind-expanding” [1] tool had attracted many academicians as well as practitioners. With the advance of the digital era signified by the explosion of the amount of potentially useful information on the Internet and increasing integration of IT with business processes, the need for adequate decision support means becomes even more profound [46]. However, the traditional notion of DSS as that of an advanced, but detached “island” system does not adequately meet the requirements of today's dynamic highly networked environments. Current trends towards higher integration of diverse systems with business operations require a tighter link between DSS and problem domains [4]. Furthermore, the competitive forces demand faster reaction to changes in the business environment.

The purpose of this paper is to convey a vision for a situated DSS: the one with more intimate relation with its problem environment. Such a DSS should have (possibly advanced) means of directly accessing and acting upon the current state of affairs in the environment. Furthermore, in our opinion, the three phases of Simon’s problem solving model (Intelligence/Design/Choice) that saturate the DSS literature should be complemented with the implementation phase for the new generation of DSS. Such an expansion has become a reality nowadays, primarily due to the advance of the Internet and the development of the new fields, such as software agents and multi-agent systems.

In the following sections we will analyze the changing role of DSSs in the new age and present a notion of a “situated” DSS. We will elaborate on the means of linking such DSSs with the environment and a user, and argue in favor of agent-based approach for building them. We will further review some possibilities for employing such systems in various e-business contexts. We will finally propose an agent-based architecture and describe a prototype to illustrate our approach.

2. The changing role of decision support

Decision Support Systems have been one of the most popular areas of research in Information Systems [11]. However, lately the interest in DSSs has been declining as witnessed by the number of publications. This is a somewhat unexpected observation, since in the new economy the need for decision support is becoming “ever more pronounced” because of the huge amount of information available on the World Wide Web [46]. E-business presents very powerful opportunities in application of decision support tools. The predictions are made about the emergence of a “new breed of consumer...
... more selective, better informed, and with a range of powerful tools at his or her disposal” [32]. It is, therefore, of utmost importance to identify ways of enhancing the traditional DSS to fit the needs of the new world. But what are these needs?

In new type of organizations improving strategic capabilities involves combining knowledge with speed [21]. Using an analogy of a computer-supported airplane pilot, the concept of “managing by wire” as it applies to management of organizations advocates the use of IS power to combine high level decision making with proactive automation and support necessary for facilitating business operations [20]. The terms “cockpit of the business” [20] and “cyberspace cockpit” [32] have appeared to signify the new vision of computer-based supporting tools.

One important requirement for the new generation of support tools includes the increased level of proactiveness. The need for more active decision support has been stressed since the late eighties [2, 10, 24, 31, 39, 40]. The advocates of active DSS criticize 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 the new paradigm for active DSS is an important development, it is not sufficient to fulfill the requirements of the digital age.

The predominant characteristic of our age is high level of connectivity that pervades multiple aspects of managing and conducting business activities. This phenomenon of “ubiquitous network” should be the focus of modern DSS researchers [46]. However, the whole conception and perception of Decision Support Systems from the very beginning has been that of a problem solving, or “mind expanding” tool [1], placed above and in some sense detached from the sphere where actual business operations or transactions take place. While there has been some criticism of such “stand-alone” DSS approach in favor of DSS linked with business work processes [4], this theme has not yet gained powerful support in DSS community.

The inherent constraint in expanding traditional DSS out of the “detached problem solving” realm and into the dynamic realm of business operations has been the wide adoption of the three phases of Simon’s problem solving model incorporating Intelligence, Design, and Choice phases. Although later Simon included “monitoring” phase, the first three phases have largely remained the holy “trinity” of DSS research. Some DSS researchers suggested use of alternative models [3], e.g. Mintzbergh’s model for the design of DSS [8]. While definitely having contributed in a very positive way to the DSS area, Simon’s three-phase model does not adequately integrate with the “ubiquitous network” metaphor.

The major purpose of the current work is to signify the need for the new generation of DSS. These systems will combine the cognitive strength of the DSS in the traditional sense and the connectedness to the problem environments. These systems will have means to sense the problem environment, provide decision support to a decision maker and act upon the environment to adequately respond to the needs of the today’s businesses. In other words, these will be the situated Decision Support Systems.

3. Situating the DSS

Within last few years a broad category of software units referred to as “agents” has gained tremendous popularity. One central theme in agent technologies is their situatedness in the environment. Jennings notes that “an agent is an encapsulated computer system that is situated in some environment and that is capable of flexible, autonomous action in that environment in order to meet its design objectives”[25]. Another description of an agent reads “an autonomous agent is a system situated within and part of an environment that senses that environment and acts on it, over time, in pursuit of its own agenda and so as to effect what it senses in the future” [17].

Comparing traditional Artificial Intelligence with the agent approaches Maes notes: “traditional AI has focused on ‘closed’ systems that have no direct interaction with the problem domain about which they encode knowledge and solve problems. Their connection with the environment is very controlled and indirect through a human operator. An agent is ‘situated’ in the environment. It is directly connected to its problem domain…” [29] (Italics added). This comparison, which can be easily extended to DSSs in general, very precisely pinpoints the problem with the traditional DSS that we have stressed earlier. There is little doubt that this situated nature of agent-based technologies, the adequateness of this approach for timely and directly responding to the developments in problem environments grossly facilitates the growing popularity of software agents.

It follows, then that situating DSS within a problem environment, linking it to the means of directly sensing the relevant data, and issuing control signals to change the environment can bring about the type of decision support that today’s organizations need. Such a system could be referred to as a “cockpit of business”, or a “cybercockpit”, but in our opinion, the better term to describe it would be “Decision Station” (DS). Having such a system at their disposal, the decision makers could “buckle up” and use it to sense what’s going on in their respective problem domains, utilize traditional DSS facilities to inform their decisions, make the choices and
change the state of affairs through the digital tentacles of the situated system.

Figure 1. depicts a general architecture for a Decision Station. Its kernel is composed of the traditional DSS facilities, including databases, models, and knowledge bases relevant to a problem domain. Borrowing from the agent-based technologies we have extended the DSS kernel with “sensors” and “effectors” [25, 29]. The role of sensors is to capture the data that is relevant to problem domain from the variety of sources. The sensors however should not be thought of only as mere means of capturing the data. They may actually incorporate more complicated functions, i.e. search of relevant sources, filtering and pre-processing of data, alert generation and other useful features. The effectors are the devices by means of which a Decision Station sends out a signal out into the problem environment with the purpose of directly or altering current state of affairs. Similar to the sensors, the effectors are not necessarily simple vehicles of decision execution or communication, but may incorporate certain level of complexity, or even intelligence, e.g. they could be converting the decision into more detailed plans, optimizing the well structured aspects of a decision, determining sequence of actions, monitoring execution of a decision, and, possibly, even conducting negotiation in the course of implementing a decision.

We have also added enhanced user interfaces, to signify new ideas and developments in facilitating human-machine dialogues. Such interfaces may incorporate synthetic characters, reside on wearable devices, and have learning capabilities.

3.1. Sensors: accessing the state of affairs

Finding new relevant information can contribute to all phases of Simon’s model, but most notably it corresponds to the intelligence phase. In a DS this task is performed by means of sensors. By sensors here we imply a wide variety of tools use to locate, access, filter and interpret relevant information from the environment. With the explosion of the information available in electronic form on the Internet the task of finding the right sources, filtering useful information and presenting it in a suitable way to a decision maker has become of crucial importance. Hence, it is not surprising to see the growth of smarter, more advanced tools used for these functions. In particular, the growth of interest in agent technologies employed on WWW signifies this trend.

The sources of information could vary significantly. They could be embedded in physical environments, various databases, or WWW. Synergizing physical and virtual environments is an imperative task of our age [22]. In [16] a device that combines PDA and a GPS receiver is described for supporting shopper’s task in a physical mall. The sensors situated in the Internet include such tools as archie, gopher, netfind, and others [15]. In [44] a decision-centric information monitoring is described with the sensors assessing the relevance of the change in data to the decision at hand.

![Figure 1. A generic architecture for a Decision Station](image)

Figure 1. A generic architecture for a Decision Station

As we already mentioned, agents nowadays play a role of advanced sensors possibly with encapsulated intelligent capabilities. In [37] agents access information from airline databases to support travel planning. Bui & Lee propose an agent based DSS where embedded agents monitor, gather and filter relevant information in geographically distributed environments [9]. In [14] a “cognitive” agent is described designed to amplify human perception and cognition in critical environments. Sycara et al. propose an elegant architecture for agent-based information gathering in support of decision making [48].

3.2. Effectors: extending digital tentacles

While in the past the means of linking DSS outputs to the problem environment were rare, nowadays such link becomes a reality in a more networked, more integrated world. Businesses not only need means for accessing the vital information, but also those for responding quickly and as directly as possible to the changes in a dynamic environment. Empowering DSS with “digital tentacles” - the implementers of decisions - is becoming a reality today. This is mainly achieved through the advance of a ubiquitous network and its pervasion of major business
processes [41]. As a consequence, in a modern world there is less need to “switch media” while moving from decision making to decision implementation [32].

Moreover, implementation in general may involve not only carrying out the decisions, but necessary planning, monitoring of execution, review, and such advanced processes as negotiations. Therefore, the effectors too in general may need a “mind” of their own to accomplish the final decisions produced by DSS.

The effectors can potentially reach not only the virtual world, but also the physical one. In fact, 98% of the computing power is embedded in different types of devices facilitating proactive computing with humans placed “out and above the loop” [50]. While the interfaces for such devices allowing integrating them with the Internet are being developed, this tremendous power would enable decision makers to use their judgment to directly manipulate the physical environment.

The means of manipulating virtual objects in the Internet include such tools as ftp, telnet, mail, and others [15]. These could be encapsulated in effectors that may in addition have more capabilities. For example, an effector with the optimization capabilities [13] may finalize the details, find the best way of carrying out and overview the execution of human decisions.

Another possibility is to delegate the authority and capability to conduct automated negotiations within a certain range of criteria to the effectors as part of the decision implementation process. For example, production decision may require purchase of certain items from suppliers within a certain price range, and effectors could negotiate the exact price with the prospective suppliers.

### 3.3. Enhanced interfaces: towards advanced collaboration

While the human-machine synergy has always been an idealistic vision for the DSS it has not happened in the past [10]. Nowadays, decision makers can easily be overwhelmed with the amount of information and multitude of modeling tools available through their computers. Hence, the task of designing effective user interfaces becomes profoundly important.

With the growth of the web one can expect more user interfaces having web-based browser-like characteristics. For example, [6] describes a web-based consumer DSS using a data warehouse to support healthcare decisions. O’Keefe & McEachern discuss the cases of web-based customer DSS that allow the decision maker to locate relevant information and perform simulations using web browsers [38].

While basing user interfaces on WWW browser-like formats promotes standardization and familiarity level of users as well as places minimal requirements on their geographical location, a higher level of human-machine collaboration can be achieved through promoting more active interfaces. Such mixed-initiative interfaces could help alleviate information overload by combining direct manipulation with the automation [23]. As Negroponte predicts: “Future human-computer interface will be rooted in delegation, not the vernacular or direct manipulation” [35]. These interfaces populated with personal digital assistants and virtual secretaries will be able to perform multitude of tasks, including scheduling, filtering information, learning user preferences and many others in an (semi-) autonomous fashion [5, 23, 29, 45].

There are also some other, more exotic directions in building new interfaces. For example, Streitz et al. argue that the physical work environment including room elements and furniture can be used as part of the user interface [47]. They coined the term “roomware” and built some prototypical elements of such an interface to demonstrate their approach.

### 4. Agents as building blocks for a Decision Station

As one can notice, the above review of the means for enabling the situated DSS largely correlates with the use of agent technologies. This should’nt be surprising, since agents have the characteristics that fit quite well the task of linking DSS to the problem environment. The list of these features includes [17, 29, 53]:

- Situatedness;
- Autonomy;
- Proactiveness;
- Intelligence;
- Social ability;
- Reactivity.

Situatedness is the feature that helps sensors and effectors link to the respective problem environments. The target environment could be either virtual, or physical one, or it could span across both. Autonomy and proactiveness are necessary for allowing the components of a system to take initiative and execute various related tasks in an automated fashion. Intelligence may be required for performing high-level cognitive tasks, e.g. negotiations. Social ability allows the situated DSS to communicate with other systems as well as the user; and reactivity enables monitoring the environment, or the user to signal and handle significant problem-related events.

Use of agents for building active DSS has been proposed earlier [2, 10, 48, 52]. For example, Angehrn proposed a vision where a decision maker is supported by a team of stimulus agents forming a virtual teamwork [2]. Sycara et al. proposed a layered architecture where
various agents inform decision makers with the illustration of portfolio management [49].

We have already described the possibilities of use of agents as parts of sensors, effectors, and interfaces. These are important directions of research facilitating the higher degree of DSS situatedness. An interesting question is: whether agents can also be used as supporting tools in a problem-solving sense in a DSS, i.e. in the kernel of a Decision Station. Such a “purely” agent-based DS could offer the advantages of proactive support and high-level integration of DS components. We will propose one such possibility when we describe architecture for an agent-based DS in later sections.

5. Employing Decision Stations in the digital age

The fact that a large share of economic activities can be performed using digital networks opens wide opportunities for the employment of autonomous agents for executing them. It is reasonable to expect radically new ways of conducting economic activities and emergence of new types of economic institutions (distribution channels, supply chains, markets, etc.) involving the empowered agents [28]. Yet, even the proponents of agent-based technologies agree that there is a good share of tasks that cannot be fully automated [12, 30, 43]. These semi-structured tasks [42] require the human to remain “in the loop”[30] and call for a decision support approach [34].

Orientation towards semi-structured problems is at the very heart of the concept of DSS. In order to tackle these problems, the aforementioned Simon’s model of Intelligence, Design, and Choice has been traditionally employed. In [33] a link between this model and early stages of Consumer Buying Behavior (CBB) model is made. It includes search for products (design); management of search criteria (intelligence); and comparison of products (choice). Other ways of describing early-stage tasks in CBB include: need identification, product brokering, merchant brokering, and negotiations [19, 30]. In order to include later stages of CBB, one has to extend the three-phase model by the Implementation phase. Basing on the existing agent-mediated e-commerce literature, the tasks for this phase could include: settlement, payment, delivery, after-sales support, evaluation, and transaction analysis (and possibly some minor negotiations). This list can be extended further if one takes into account intra-business and business-to-business perspectives.

We will look at some ways to facilitate our vision for building Decision Stations for e-businesses from the Intra-organizational, business-to-business, and business-to-customer perspectives.

5.1. Intra-organizational perspective

In this perspective we are concerned with situating DSS within the organizational IS infrastructure, translating decisions into the form suitable for managing, controlling, or supporting operations, and sending the outputs to the relevant systems, people or devices responsible for execution of these operations. For example, product quantity decisions made with the use of DSS incorporating various models (e.g. forecasting) and data sources (e.g. historical data) should be sent directly to MRP systems (and other relevant destinations) responsible for ensuring that the necessary resources will be available. Probably, the best basis for building such a situated DSS is enterprise-wide software.

An example of a DSS that supports implementation and control processes (in addition to Intelligence, Design, and Choice) is given in [27]. The important milestone in this direction is building solid interfaces between IS and the operations [18]. In production, this would involve establishing full integration of DSS and Computer Integrated Manufacturing. In services, the DSS can be linked to the workflow systems. In the future we will also probably see DSS linked with the agents managing some business processes [26].

5.2. Business-to-business perspective

In business-to-business perspective Decision Stations should ideally be connected to the means of performing transactions with other businesses. This can be accomplished by the tools forming the “services” layer of e-commerce including: EDI and open-EDI, EFT, e-money, smart cards, agents, and other vehicles [54]. While traditional EDI has been very successful, its use is limited to larger companies with stable business partners. For achieving higher flexibility and affordability of business-to-business transactions, internet-based EDI and virtual marketplaces are developed. For example, in [7] a prototypical virtual marketplace RMP is discussed, where buyers may check the delivered products, accept them, file complaints, or deny acceptance of deliveries. Supplier can review details of accepted/rejected orders, shipment information, and issue invoices.

A new stream of research in supply chain management envisions use of intelligent agents for managing supply chains [12, 36]. For example, in [12] agents compose the RFQ contents and use utility function to evaluate bid assignments to tasks. However, the decision makers can override agent recommendations. Actual execution of the transactions can be delegated to so called “transaction agents” [42].
5.3. Business-to-customer perspective

From business perspective the managers should have means of directly implementing their decisions, e.g. setting prices and executing policies. From the customer perspective the customers should not only be informed by a Decision Station about the choices they make, but also have the means to implement those choices. For example, in on-line banking a customer can not only view important financial information (his/her account balances, current exchange rates) and make simple calculations (e.g. estimate amounts in different currencies), but actually execute his/her decisions (e.g. transfer balances) without having to call or physically go to the bank. A more advanced capabilities are offered by the on-line trading, where an investor can get access to a wide variety of relevant information, financial models, and expert opinions to inform their choices, and also place orders of various types on-line.

Decision support in e-commerce empowers customers in a radically new way [32], overcoming the traditional limitations of bounded rationality. This especially becomes true with the advance of “agent-mediated e-commerce” [19]. Agents can perform a multitude of support tasks for the user, such as comparison shopping, searching for the suitable offers, conducting negotiations, providing guidance to the decision makers, managing shopping cart, and overviewing execution of transactions.

6. An Architecture and a Prototype for Agent-Based Decision Station

This section discusses architecture for a Decision Station incorporating different agents (Figure 2). This is an extension of an agent-based DSS architecture discussed elsewhere [51]. The architecture consists of two parts: the objects (passive entities) and the agents (active doers). The major components of the architecture include: Interface; Data & Models (Entities); Intelligence & Implementation Team (Agents); Design Team (Agents); and Choice Team (Agents). The suggested naming attempts to reflect the roles of agents according to the decision making process.

The Interface provides interaction between the user and the system. It also can be implemented as an agent, e.g. to elicit and maintain user profile. The Data and Models contain the data and models relevant to decision making. The user can access the data and models just as in the traditional DSS to extract information from the database, do useful calculations and what-if analysis using models, and perform other related tasks. The Data & Models also provide information to different agents if required.

The Intelligence and Implementation Team contains intelligence and implementation agents (sensors and effectors). The purpose of intelligence agents is to obtain relevant information. The purpose of the implementation agents is to execute the decisions made by the decision maker. For example, this could include requesting the user what method of payment he/she would prefer, making payments on the user’s behalf, and monitoring the delivery of ordered goods.

The other two groups of agents are “problem-solving” agents.

Figure 2. Architecture of an agent-based Decision Station

The Design Team incorporates agents for generating alternative suggestions. Agents in this group propose alternatives that should be weighed by the decision maker in making economic decisions. The name for a team corresponds to the design phase of problem solving model that deals primarily with generation of alternative courses of actions. Each proposing agent in this team is using its own unique model in recommending a decision. The agents not only suggest different alternatives, but also the ones that are diverse. One could diversify in respect to the desired objectives of a decision, as well as to the way these objectives are achieved. In other words, one can identify different values in making a decision (e.g. maximize quality, minimize cost, etc.) as well as different views on how to achieve a given objective (e.g. how to choose a quality product).

The agents of the design team adopt different values & views while making their recommendations. Examples of value-diversified suggestions in a book buying context would be:
• Agent suggesting the lowest-price book;
• Agent suggesting the book with the best delivery time;
• Agent suggesting the best quality (e.g. based on cover, paper type) book;
• Agent suggesting some combinations of the above.

The Choice Team consists of two types of agents: the positive and negative critique agents, also referred here to as the "angel" and the "devil" respectively. These agents critique the proposals generated by the proposing team, as well as those modified/specified by the user. The design of such critiquing agents has been elaborated elsewhere [52]. The critique is organized around the objectives, preferences, and soft constraints of the user. For example, in a book buying scenario, one possible critique could be that the proposed book is somewhat expensive considering buyer’s budget. In a nutshell, the system generates a set of good diverse alternatives with pros and cons outlined, and facilitates the execution of the final decision.

We have developed a prototype for an investment Decision Station. In our prototype only design and choice teams have been implemented so far; however the prototype can be potentially expanded to include the remaining types of agents also. Figure 3 shows a sample screenshot of user interface (actual names of stocks are coded). The data for different securities had been pre-downloaded from electronic resources.

The Design Team consists of two assisting agents, called analysts and four proposing agents (proposers). The proposers and the analysts help to identify a small subset of perspective securities, from which the proposers determine their portfolios and submit them to the user. The two analysts are designed so that they incorporate different sets of views, namely, two well known different schools of thought in security analysis: Fundamental Analysis and Technical Analysis. Therefore, analysts are the sources of expertise in the two corresponding schools. The analysts differ on the view dimension of the prototype.

The four proposers determine the portfolio based on the analysts' recommendations and the values (sets of objectives) they employ. The value dimension of the proposers adopted here is their attitude towards risk, since this is one of the major concerns in selecting adequate portfolio. Each analyst advises two proposers. One of these proposers in each of two groups is risk taker, while the other is risk averse. Therefore, the alternative investment scenarios reflect four distinct attitudes:

- technical analysis/risk-taking;
- technical analysis/risk-averse;
- fundamental analysis/risk-taking; and
- fundamental analysis/risk-averse.

The agents of the design team use rule-based methods as well as heuristic search techniques to generate proposals. Note that within adopted value-view an agent tries to find an “optimal” solution.

The Choice team consists of two critiquing agents: the Devil and the Angel. These agents analyze and critique the proposed portfolios. There is a number of important factors taken into consideration while making investment decisions. These factors include: expected return and risk, user preferences and the source of alternative portfolios.

Generally, one seeks to maximize return while keeping risk at a minimum level. This knowledge can be used for providing objective-related critique. If the user chooses a portfolio with the average expected return being high, the "angel" would detect that and tell user that "the expected return of this portfolio is high". The "devil", on the other hand, may detect high risk associated with the proposed allocation and prompt it to the user.

The preference related critique examines the solution from the point of view of the user’s preferences. If the user is a risk taker high risk would trigger the positive critique commenting on the appropriateness of the portfolio to the user's risk preference. On the other hand, if the user is risk averse, the negative critique would identify the inadequate risk level.

In the prototype the user is provided with four investment alternatives by four different proposing agents based on the current market situation and the results of analyses of this situation. The user can browse and view information on different securities, including historical information, fundamental and technical indicators, and also graphs of security performance. The user can select
the securities into the portfolio, and do simple calculations of portfolio characteristics including the expected risk and return on a portfolio. In addition to numeric feedback the user also receives the verbal assessment of a portfolio from the critics organized into “pros” and “cons”.

The user can select the proposals generated by the proposing agents as well. These agents generate “good” portfolios that fit their views and values. The user can analyze and modify these portfolios while receiving a feedback from critics. This iterative process ends when the user is satisfied with the portfolio. Clicking on “Done” button would initiate the processes of selecting a type of and placing an order, executing payment, and other transaction-related processes currently not implemented in the prototype.

6. Conclusions

The main purpose of this paper has been to indicate the need for a new vision for a DSS that better fits the requirements of the digital economy. We articulated this vision as a notion of the Decision Station: a situated Decision Support System, the one with the intimate link to its problem environment. We have presented a generic architecture for such a DSS and elaborated on its basic components. We have argued in favor of an agent-based approach to developing Decision Stations. We have reviewed some possibilities of employing the situated decision support in different segments of e-business. We have further proposed an agent-based architecture for the Decision Station and described a prototype for investment decisions. While future research is needed in the design and empirical assessment of the proposed class of systems, we believe, that the significance of the connected DSS will grow in the future.

7. References


