An Overview of Decision Support System Concepts

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Abstract. *This paper presents an analytical overview of Decision Support Systems (DSSs) – a widely used, but insufficiently systematically described term, which covers a variety of types of information systems aimed to support human decision making. Introduction to the issue is briefly presented. Description of key terms, definitions and taxonomy problems follows, trying to turn the existing confusion into some order. Further, main ideas and characteristics of different types of DSSs are elaborated, putting the emphasis on concept rather then technology. Two types of DSSs – model-driven and knowledge-driven DSSs are considered in more detail. At the end of the paper, some actual research problems are pointed out and possible solutions to those problems are suggested.*

Keywords. Decision support, decision support systems, model-driven DSS, knowledge-driven DSS

1. Introduction

Although the term "Decision Support" (DS) and thus "Decision Support System" (DSS) seems to be simple and intuitive, it also seems to be hard to find an acceptable definition. It is therefore hard to define DSS characteristics and taxonomy as well.

Number of definitions grows with number of authors involved in this problem area, which leads to confusion about fundamental DSS concepts.

Possible reason for lack of an actual systematic overview of DSS is the appearance of a variety of terms, often synonyms, describing some narrow problem area specializations. Moreover, specifics of scientific fields by authors dealing with DSS leads to different perspectives of what DSS should be.

However, DSS remains an aggregate term for many different information systems and more increasingly a needful tool.

This article attempts to describe DSS conceptually and to put the terms related to DSS and associate keywords "in the right place". It also describes some DSS specializations to more detail and points out some actual research problems in this field.

2. What is a DSS?

2.1. Decision making

Making decisions has always been immanent to human nature. Supporting the process of decision making is a scientific research area throughout history, which involves many science disciplines such as statistics, information science, psychology, economics and others. The idea of computer-supported decision making appeared in theory in the late 1960-ies. The first realizations and implementations of DSS arose in 1980-ies.

2.2. Decision Support

Keen [6] claims that it is impossible to give a precise definition of DSS including all its aspects: "There can be no definition of *decision support systems*, only of *decision support.*"

However, attempts to define the DSS with no definition of DS previously being accepted, are present and are becoming even more frequent, as we shall see in a further chapter.

In his definition, Bohanec [2] emphasizes that DS is concerned with human decision making, as opposite to machine decision making, which is rarely mentioned in definitions:

"Decision Support (DS) is a broad, generic term that encompasses all aspects related to supporting people in making decisions."

Although these two types share many methods, their principles are different.

2.3. DSS definition problem

According to the previous section, we can say that DSS is one of the DS disciplines supported by computer, but there is no universal definition of it. Some of the most cited ones are:

- *Sprague and Carlson [10]*: "DSS is an interactive computer-based system that helps decision makers to utilize data and models to solve unstructured problems."
- *Finlay [3]*: "DSS is a computer-based system that aids the process of decision making."
- *Turban [12]:* "DSS is an interactive, flexible, and adaptable computer-based information system, especially developed for supporting the solution of a non-structured management problem for improved decision making."

Considering above definitions, DSS ranges from systems answering of simple queries to systems modeling of a complex human decision making process. Therefore, it is easy to put a variety of information systems into the DSS class. Then, what does it make a DSS different from other information systems?

2.4. DSS characteristics

Without a consensus regarding the DSS definition, it is not easy to find the consensus about DSS characteristics.

Often cited, crucial, but still very broad DSS characteristics defined by Alter [1] are:

- DSS are designed specifically to facilitate decision processes.
- DSS should support rather than automate decision making.
- DSS should be able to respond quickly to the changing needs of decision makers.

However, some more characteristics need to be added:

- DSSs incorporate both data and models [11].
- DSSs objective is to improve the effectiveness of the decisions, not the efficiency with which decisions are being made [11].
- DSSs provide support for decision makers mainly in semi-structured and unstructured situations by bringing together human judgment and computerized information [13].
- DSSs must be designed to interact directly with the decision maker in such a way that the user has a flexible choice and a sequence of knowledge-management activities [5].

2.5. DSS taxonomy

Different authors will not agree about taxonomy either.

Partitions chosen in the further text are not a result of consensus, but in authors' opinion, they are closest to be comprehensive and complete. So, for every criterion mentioned, one partition is chosen.

There are many criteria by which DSS can be systematized.

The most general is the mode of assistance criterion. Power [2] differentiates five types of DSSs using the mode of assistance as a criterion: Document-driven, Communication-driven, Data-driven, Model-driven and Knowledge-driven DSS.

- *Document-driven DSS* supports decision making by searching and retrieving right documents.
- *Communication-driven DSS* uses network and communications technologies to facilitate collaboration and communication, and thus makes decision making faster and more productive.
- *Data-driven DSS (DD-DSS)* supports decision making by analyzing given time-series of data and returning new information gained by those analysis.
- *Model-driven DSS (MD-DSS)* models decision problem using analytical and optimization tools and suggests actions.
- *Knowledge-driven DSS (KD-DSS)* represents specialized knowledge and supports decision making in a particular domain.

Considering the relationship with the user criterion, Hättenschwiler [4] divides DSS into three groups:

- *Passive DSS* – aids the process of decision making, but cannot bring out explicit decision suggestions or solutions.
- *Active DSS* – brings out explicit decision suggestions or solutions.
- *Cooperative DSS* – allows the decision maker to modify the decision suggestions provided by the system. The process is then repeated until a satisfying solution is generated.

Taking the scope as a criterion, Power classifies DSS into two groups:

	Keywords	Other names	Platform	Methods	Examples
Document-Driven DSS	document databases, document retrieval, document analysis	/	Client/server systems, web	search methods, storage and processing methods and technologies	search engines
Communications-Driven DSS	communications, collaboration, groupware	/	client/server systems, web	network technologies	chats software, document sharing, online collaboration, net-meeting systems
Data-Driven DSS	manipulation of a time-series of data, query a database, historical data	Retrieval-Only DSS Business Intelligence	mainframe system, client/server systems, web	data warehouse, on-line analytical processing (OLAP)	Executive Information Systems (EIS), Geographic Information Systems (GIS)
Model-Driven DSS	model manipulation, simulation, optimization, rule (expert) models, analyze decisions, multi-criteria, decision tree	Model-oriented, Model based, Computationally oriented DSS	stand-alone PCs, client/server systems, web	optimization and analytical methods, operational research methods (quantitative methods)	choosing between many options (“the best” alternative: "the best" meal, "the best" car), scheduling,
Knowledge-Driven DSS	expert knowledge (expertise), knowledgebase, knowledge engineering, knowledge discovery	Knowledge based DSS, Expert system	stand-alone PCs, client/server systems, web	intelligent decision support methods, data mining, artificial intelligence methods, knowledge discovery methods, heuristic methods	medical diagnosis, equipment repair, investment analysis, financial planning, vehicle routing, production control and training

Table 1. DSS types and their characteristics

- *Enterprise-wide DSS* – multi-user DSS that runs on a server machine
- *Desktop DSS* – single-user DSS that runs on a personal computer (PC)

It is possible to build a DSS in almost every knowledge domain. This is a list of the most popular DSSs using knowledge domain criterion (the list is not final):

- *Medical diagnosis DSS* – helps the clinician to reach an accurate diagnosis
- *Financial planning DSS* – helps managers to increase the profit of the company
- *Spatial DSS* – helps decision-makers to solve complex problems related to geographic or spatial data.

Table 1 gives an overview of DSS types by mode of assistance. The table shows DSS types in rows and their characteristics in columns.

The characteristics are following:

1) *Keywords* – The list of most common terms associated with a particular type of DSS.
2) *Other names* – Through the history, DSSs have evolved from theory to practice, and thus they have often passed through some name-changes, listed in this column.
3) *Platform* – Although today almost every application migrates to web, it is worthwhile mentioning the main platform for each type of DSS.
4) *Methods* – The list of some methods used for solving decision problems in a particular type of DSS.
5) *Examples* – To get a more complete picture of different DSS types, some examples are listed as well.

For example, most common keywords for KD-DSS (last row in Table 1) are the expert knowledge, knowledge engineering and knowledge discovery. Terms that also refer to KD-DSS are *Knowledge based DSS* and more

often, in modern times, *Expert system*. KD-DSS can run either on a desktop PC or on the web. Some of the most used methods for solving problems related to KD-DSS are data mining, artificial intelligence methods, other heuristic methods... Finally, examples of KD-DSS are systems helping in medical diagnosis, investment analysis, (vehicle) routing etc.

In real life, a particular DSS can have characteristics of more than one type, i.e. overlapping of types is not impossible.

In further text, DSS is considered in the context of the mode of assistance criterion.

3. Concept of DSS

Communications-Driven DSS is a type of DSS that emphasizes communications, collaboration and shared decision making support [8]. It merely serves as an infrastructure that enables messaging, while humans perform all decision making. The decisions are mostly "verbal" and generally, the system does not store the results of decisions.

Document-Driven DSS is a relatively new field in Decision Support. Document-Driven DSS is focused on the retrieval and management of unstructured documents [8]. Similar to Communication-driven DSS, it merely serves as an infrastructure.

Data-driven DSS originates from databases, where the components, methods (Data Warehousing and Online Analytical Processing) and technologies are well defined and elaborated.

The focus of this article further on will be on two other types of DSS: Model-driven and Knowledge-driven DSS.

In following sections, a more detailed schematic view of these two types is presented, trying to give the answer which type of DSS to use when one is faced with a concrete problem.

3.1. Model-driven and Knowledge-driven DSS

A simplified preview of main objectives and differences between MD-DSS and KD-DSS is presented in Figure 1.

The Figure consists of five components:

1) *User – a* person who uses DSS
2) *User Interface* – part of the system which communicates with the user; described to more details in the next chapter

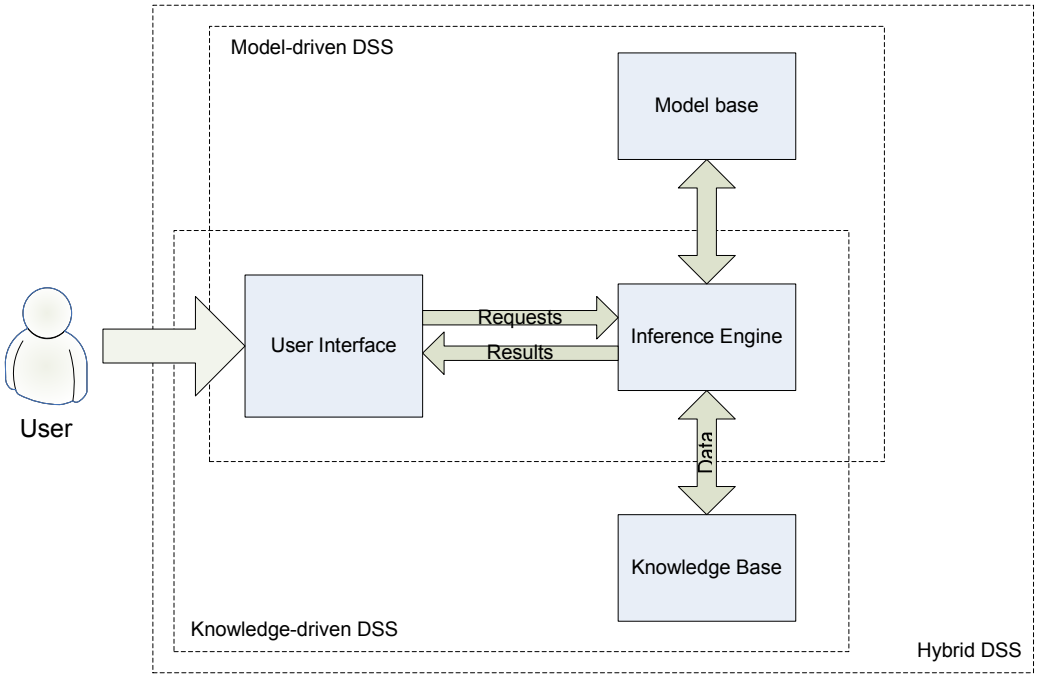

Figure 1. Decision Support System conceptual schema

3) *Model Base* – a set of analytical and optimization tools which perform the decision making process
4) *Inference Engine* – a part of the system which makes conclusions
5) *Knowledge Base* – information (knowledge) including data and rules stored in a database

Links (arrows) between these components contain data, which flow through the system:

1) *Requests* – refer to user requirements entered through the user interface; they are more or less adapted – depends on user interface; they are sent to Inference Engine, where they are processed
2) *Results* – solution to user requests sent from Inference Engine to the User Interface
3) *Data* – requests for data, or new information from Inference Engine; and data achieved from the Knowledge Base component

In a Model-driven DSS, the main role plays Model Base, while Knowledge Base is not necessarily present. Data are received either through User Interface and sent to Model Base, either stored to data store by loading a file or have been previously collected. The amount of data used in the model-driven DSS is small.

In a Knowledge-driven DSS, the central part is Knowledge Base (i.e. a large amount of data representing knowledge from specific domain and relationships between the data). Inference Engine performs the whole decision making process with regard to user requests.

A problem area often necessitates both a mathematical model and a large database to be present and we do not have clear difference whether the system belongs to a MD-DSS or KD-DSS. In such a hybrid DSS, both the Model Base and the Knowledge Base are present.

4. Problems (research topics)

As it has been already pointed out, DSSs deal with human decision making. Thus, they have to deal with human inconsistency and uncertainty as well.

One of the aspects for improvement can be the user interface.Another improvement can be found in representing of decision problem and decision problem solving methods.

Most of the problems are not new, they have been in the research focus of many scientists, but a need to find ever better and better solutions is surely still present.

More about the user interface and some specific problems in MD-DSS and KD-DSS are introduced in following sections.

4.1. User Interface

User Interface (UI) is a very important part of any system, especially for systems in which communication with the user is crucial for system's performance. Hence, a user-friendly and clear UI is needed in DSS.

UI has to be logically divided in two parts. In the first part the user defines his or her requests. They can be entered as a text or chosen among offered options. Furthermore, they can be entered and sent at once or led step by step according to previously chosen options.

In the second part, the system returns results. Results can be represented textually or graphically, but they should be shown with corresponding weight.

4.2. Problems in model-driven DSS

Most of the problems in model-driven DSS concern decision making and decision theory problems, such as:

1. Uncertainty.

Very often, it is impossible to determine complete and unambiguous information. Choosing the right representation of such information can be crucial to make a right decision.

2. Inconsistency.

Avoiding human inconsistency is impossible, but some mechanisms to deal with inconsistent data or at least to notify if contradictory information exists are necessary.

3. Multi-criteria decisions.

Finding the optima in multi-criteria decision problem requires also attribute ranking. The problems are how to measure such a thing and how to combine measurements to produce a decision.

4. Decision instability.

Finding a solution is one part of the problem, another one is to find a stable solution. Decision should be carefully analyzed and presented with its advantages and disadvantages.

4.3. Problems in knowledge- driven DSS

Most research topics in knowledge-driven DSS relate to the following problems:

1. Representing the knowledge.

Expert knowledge is represented by rules. The easiest form is if-then rule, but reducing a part of an expert knowledge to such a rule is sometimes impossible. System should be able to handle rules that are more complicated.

2. Getting knowledge from experts.

It is reasonable to think that experts are not going to write down if-then rules. The need for a suitable interface, yet likely to native language, is inevitable.

3. Resolving rules conflicts.

Setting the rules by humans naturally leads to rules conflicts. A good algorithm for resolving that problem is needed.

4. Producing a conclusion.

Both knowledge facts and rules arise from large amount of data. Producing a conclusion in acceptable period of time becomes very important.

5. Learning.

Recently, an actual topic is computer learning. The possibility to incorporate learning in the process of decision making sounds very attractive.

Some new trends in solving some of above problems are incorporating fuzzy logic and a growing number of heuristic algorithms in modeling of the decision making process.

5. Conclusion

This paper is a brief overview of a very broad field of Decision Support Systems.

The problem of absence of a commonly adopted definition and taxonomy is observed. The most used definitions are presented. Categorization of this type of information systems according to its characteristics is updated and corroborated. Concepts, differences and similarities of Model-driven and Knowledge-driven DSS are described. Main research problems are briefly presented as a direction for further improvements.

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