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A Framework for Decision and Intelligence Systems based on Input and Output Types

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Abstract

In tracing the evolution of computer based Management Support Systems (MSS), three main generations or classes can be distinguished. These generations, in order of their emergence, may be identified as Data Management Systems (DMS), Information Management Systems IMS), and Knowledge Management Systems (KMS). The common objective among these three classes of systems is supporting managerial decision making. One distinguishing aspect among these three classes is the type of input and output (viz. data, information, and knowledge) that these systems handle, and consequently the level and the form of support that they provide. In this paper we explore these three classes of systems from an input-output perspective. In particular, this paper offers a framework for classifying MSS based on their input and output types, with particular focus on the input side. By developing an input-output based framework for current MSS, we hope to provide a foundation to develop an agenda for the next generation of MSS.

Keywords: Management Support Systems (MSS), Data, Information, Knowledge

Introduction

One way to study the development of Management Support Systems (MSS) is through looking at the changes in the inputs/outputs of these systems. Inputs and outputs can be classified as being of three types: data, information, and knowledge. These three types mirror the journey of MSS since their conception until now. The first generation of MSS was concerned with data management (Data Management Systems). The second generation moved beyond data management and focused on information management (Information Management Systems). More recently, a new generation of MSS emerged with a focus on knowledge management (Knowledge Management Systems). A comprehensive MSS would be a system that integrates the aspects of all these classes together to support decision making, problem solving, and organizational learning. A major distinction between the first two generations of MSS (i.e. Data Management Systems and Information Management Systems) and the third generation (i.e. Knowledge Management Systems) is that the third generation has an "intelligent" or "knowledge" component which is not included in the first two generations. Knowledge Management Systems are in principle capable of making smarter decisions, explaining their reasoning and justifying their behavior (Gregor & Benbasat, 1999).

The purpose of this paper is to offer a framework for modern MSS based on their input and output types. By developing an input-output based framework for current MSS, we hope to provide insights for developing an agenda for the next generation of MSS. The paper is organized as follows: the next section will present an overview of the concepts of data, information and knowledge and the relationships among them. The following section will establish the linkage between these three types of inputs-outputs and their corresponding MSS. Next, we will offer a framework for DSS and Intelligent DSS based on their inputs. The conclusions and future outlook are presented in the last section.

Data, Information, and Knowledge: Basic Concepts

In this section, we will offer definitions of data, information and knowledge and propose a framework for the relationships among these three types of inputs/outputs.

Data are raw numbers and facts about a certain object, entity, event or transaction. Data can be thought of as a raw material that needs to be processed before it can be turned into something useful. Information on the other hand is data that has been processed and analyzed in such a way as to be meaningful to the person who receives it. Extending the raw material analogy, information can be thought of as finished goods that are readily available for use/consumption. In contrast to data and information, the definition of knowledge seems to be less clear or universally accepted. However, in the IT literature, knowledge is usually characterized by pointing out distinguishing factors from information and data (Alavi & Leidner, 2001). This paper will adopt the definition offered by Alavi and Leidner (2001): Knowledge is "information possessed in the mind of individuals: it is personalized information…related to facts, procedures, concepts, interpretations, ideas, observations, and judgments." Alavi and Leidner suggest that "information is converted to knowledge once it is processed in the mind of individuals and knowledge becomes information once it is articulated and presented in the form of text, graphics, words, or other symbolic forms". In other words, the relationship between information and knowledge is a two-way relationship. Extending the raw material/finished goods analogy, knowledge can be thought of as the personalized ways by which users go about the use/consumption of finished goods (i.e. information). Critical to this definition is that both raw material (i.e. data) and finished goods (i.e. information) exist outside of an agent whereas knowledge resides inside of an agent (a knower). This paper argues that the utility of information is personalized in that it may vary from one agent to another which is consistent with the argument that knowledge does not exist outside of an agent.

There are different views with respect to how these inputs (i.e. data, information, and knowledge) are interrelated. One common "presumed" view is a hierarchy from data to information to knowledge (Alavi & Leidner, 2001; Vance 1997). Another yet less common view is a hierarchy from knowledge to information to data (Tuomi, 1999). This paper argues that relationship among the three inputs is not hierarchical but rather cyclical. As such, we propose a third view of the relationships among these inputs. Not only does the proposed view bridge the gap between the two hierarchical views but it is also consistent with the aforementioned definition of knowledge. The following diagram represents the interaction between these inputs per the three views:

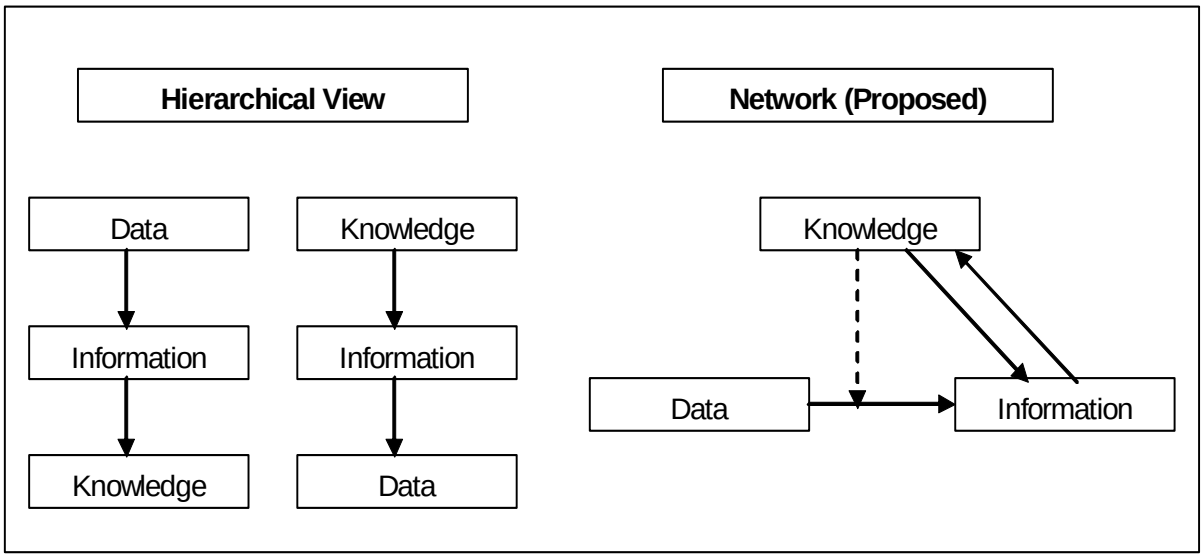

Figure 1. A Framework for the Relationship among Data, Information, and Knowledge

Mapping the Inputs to Management Support Systems (MSS)

In this section, we will draw a linkage between the three types of inputs discussed in the previous section, and the development of Management Support System. The first generation of MSS was concerned with the collection and storage of *data* from routine transactions. Transaction Processing Systems (TPS) and Electronic Data Processing (EDP) were the first applications of computer solutions to business. This paper will refer to the first generation of MSS as Transaction-Driven MSS.

The need to analyze, summarize and convert data collected by Transaction-Driven DSS and stored in databases into a useful form (hence information) for planning, controlling, and managing an organization, triggered the development of the next generation of MSS. This paper will refer to the second generation of MSS as Data-Driven MSS. Data-driven MSS are defined as "type of DSS that emphasizes access to and manipulation of a time-series of internal company data and sometimes external data" (Power, 2006).

To combine the benefits of the data from Transaction-Driven MSS and the information from Data-Driven MSS in decision making, a new class of computer systems emerged where the focus is on decisions rather than on data or information. These systems are referred to as Decision Support Systems (DSS). They support decision making by providing models for analyzing data and information. A Decision Support System (DSS) is defined as "an interactive computer-based system or subsystem intended to help decision makers use communications technologies, data, documents, knowledge and/or models to identify and solve problems, complete decision process tasks, and make decisions" (Power, 2006). While Transaction-Driven MSS and Data-Driven MSS support structured and routine types of decisions, DSS intend to support decision making and problem solving where at least some process is semi-structured or unstructured (Shim et al., 2002).

Recently, the focus has moved beyond the notion of information towards how to apply intelligence and/or knowledge on this information for problem solving and decision-making and how the knowledge of decision making and problem solving can be shared and reused to enhance organizational learning. A new generation of computer systems emerged to fulfill this purpose. These systems are referred to as Intelligent DSS or Knowledge-Driven DSS. Knowledge-Driven DSS "are person-computer systems with artificial intelligence components and specialized problem-solving expertise. The "expertise" consists of knowledge about a particular domain, understanding of problems within that domain, and "skill" at solving some of these problems in a smarter manner" (Power, 2006)

Based on the discussion thus far, we can classify modern MSS into general DSS or Knowledge-Driven DSS (i.e. Intelligent DSS). This classification has been established based on the inputs/outputs of these systems. DSS analyze data and/or information to support decision making whereas intelligent DSS apply knowledge and AI components to support decision making. In the following section, we will offer a framework for DSS and Intelligent DSS based on their inputs.

An Input/Output based Framework for MSS

The previous section established the linkage between the three types of inputs and the MSS. This section will offer a tabular framework for Decision Support Systems (DSS) and Intelligent DSS based on their inputs, outputs, capabilities and the decision phase that each class supports. For the most part, the content of the framework stems from the author's experience and understanding of MSS and their role in supporting decision making. As for the phases of decision making, this paper will adopt Simon's model of decision making (Simon, 1960). Simon described three main phases in the decision making process: intelligence, design, and choice. *Intelligence* is comprised of searching the environment for problems calling for decisions. Data is gathered and analyzed for clues that may identify problems (Sprague, 1980). *Design* involves the development of decision alternatives whereas *choice* consists of analyzing the alternatives and choosing one for implementation. Many researchers view *implementation* as a separate phase. This widely held view was adopted in the framework. Table 1 below presents the framework. The framework is put together so that it starts from early MSS and ends at the state of the art MSS.

Table 1. Framework for Classification of MSS

1- Decision Support Systems (DSS)	Inputs	Capabilities	Outputs	Supported Decision Phase
a- Transaction Driven DSS:				
Transaction Processing Systems (TPS)	Data about transactions	Data collection, storing and processing	Automated data stored in databases (DB)	Intelligence *
Electronic Data Processing (EDP)	Data about Transactions	Data collection, storing and processing	Automated data stored in databases (DB)	Intelligence *
b- Data-Driven DSS:				
Management Information Systems (MIS)	Data stored in databases (DB)	Inquiry and reporting	Information	Intelligence *
Data Warehouse (DW)	Data stored in diverse operational databases	Cleansing, integration and presentation	Integrated data (Information)	Intelligence
On-line Analytical Processing (OLAP)	Data integrated by DW	Analysis, modeling and visualization	Variety of possible views of information	Intelligence
Executive Information Systems (EIS)	Data and Information	Modeling tools, reporting and drill-down capabilities	Reports for strategic decisions (Information)	Intelligence, Design
c- Communication Driven DSS:				
Group Support Systems (GSS)	Data and Information	Brainstorming, communication & sharing	Information and ideas (decision alternatives)	Intelligence, Design
d- Model-Driven DSS:				
Optimization-Based Support Models	Data and information stored in DB and DW	Models, algorithms, and parameters	Optimal or good enough solutions	Design and Choice
2- Knowledge-Driven DSS				
Data Mining (DM)	Sophisticated data	Statistical, mathematical, and artificial intelligence	Patterns and rules, and Knowledge	Intelligence
Expert Systems (ES)	Information and domain Knowledge	Reasoning methodologies in a specific domain	Solutions to problems and courses of actions	Intelligence, Design, Choice
Knowledge Management Systems (KMS)	Domain knowledge	Artificial Intelligence	Information and knowledge	Intelligence, Design, Choice
Intelligent Agents	Data and knowledge	Data screening and filtering and Artificial Intelligence	Actions	All Phases
Directive Decision Devices (DDD)	Data and knowledge	Artificial Intelligence	Actions	All Phases

* (Sprague, 1980)

Conclusion and Future Outlook

In this paper, three types of inputs/outputs, namely data, information and knowledge, were identified, defined and a new view was proposed for the relationships among these inputs. In addition, this paper presented a linkage between the different types of inputs/outputs and several Management Support Systems. The main contribution of this paper is the framework it offers for Decision Support Systems (DSS) and Business Intelligence Systems (BIS) based on their types of inputs and outputs. Such framework is hoped to provide the reader with insights not only on the past and present of MSS but also on the future of MSS.

A major finding per the framework is that most MSS are not capable of managing the three types of inputs/outputs. This drawback is expected to negatively affect the effectiveness of the decision-making process and the responsiveness of these systems to new opportunities, threats, and problems within their environment. Another finding is that there is almost no single MSS that covers the four phases of decision making, namely intelligence, design, choice, and implementation. Only Intelligent Agents and Directive Decision Devices are supportive of all phases of decision-making. In fact these two classes of systems moved beyond the three types of outputs discussed in this paper (i.e. data, information and knowledge) by introducing action (implementation of recommended decisions) as a fourth type of outputs.

In looking at the three types of inputs/outputs, and when considering the ever-increasing flow of data from both internal and external sources, the ever-increasing amount of information and the need for enhanced organizational learning, there appears to be a critical need for a DSS that integrates the three types of inputs and the capabilities of different MSS into one comprehensive system., Such comprehensive DSS might take the form of an Enterprise-wide DSS that integrates the three generations of MSS discussed in the paper (Transaction-Driven DSS, Management Information Systems, and knowledge management systems) and that covers all decision making phases.

In conclusion, it is noteworthy that many IS researchers are now advocating for using the Web as a common platform from which to extend the capabilities of MSS (Shim et al., 2002). Additional research needs to be done on how the Web as well as Intelligent Agents and Directive Decision Devices (DDD) (Danvernport & Harris, 2005) which seem to be leading the future of DSS, can manage the three types of inputs/outputs and if there are new types of inputs/outputs that will shape the journey of the future DSS.

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