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Combination of cognitive and HCI modeling for the design of KDD-based DSS used in dynamic situations

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ABSTRACT

Recent work in dynamic decision support systems (DSS) has taken impressive steps toward data preparation and storage, intelligent data mining techniques, and interactive visualization. However, it remains difficult to deal with the uncertainty and complexity generated by the Knowledge Discovery in Databases (KDD). This paper launches the challenge by introducing cognitive modeling for specifying decision-maker behaviors more naturally and intuitively. It consists in introducing cognitive modeling for dynamic situations involving visual KDD-based dynamic DSS. This research work presents an adaptation of a well-known cognitive model under the KDD specificities. We provide cognitive modeling application in visual KDD-based dynamic DSS for the fight against nosocomial infections in an intensive care unit. Finally, we built a series of evaluations verifying the system's utility and usability.

1. Introduction

Traditionally, decision support systems (DSS) were developed to assist in the choice of multiple decision alternatives based on a set of attributes. These DSS have focused on supporting the decision-maker to choose the best possible decision based on a rational decision-making model [78,80,81]. Such model can be extracted by a Knowledge Discovery in Databases (KDD) tool. This study focuses on the KDD-based DSS [19,3,2].

DSS and KDD are widely used in the medical field [26,16,57,68,38,39], especially in the intensive care units (ICU) [23,3,52,36]. Most of the exploited ICU data are temporal; hence the decision-making process is dynamic and requires a series of decisions, where the decisions are not independent. Thus, this paper is interested in KDD-based Dynamic Decision Support Systems (DSS) [3]. These systems allow for the routines of actualization, edition, and addition of data, thus providing accurate information in the appropriate time and adequately assisting the decision-making process [24]. The dynamic decisions must be taken in real-time, thus making time constraints an important issue of decision support.

KDD-based Dynamic DSS may be highly interactive [51,54,35]. It is therefore important to understand the role of the user who can also be seen as a decision-maker in the KDD and Dynamic DSS processes. In fact, the human creativity, flexibility, and knowledge are joined with the huge storage capacity and computing power of computers in dynamic situations [44]. Hence, the idea is to combine traditional data mining algorithms with information visualization techniques: we are interested in visual KDD-based Dynamic DSS. The decision-maker in charge of this kind of systems is required to simultaneously manage a set of KDD and decision tasks dynamically. This set of KDD evolves in time and requires frequent changes in the decisional situations. The classical modeling of these situations is disclosing new potentialities, which so far are still largely unnoticed. These are mainly related to what Occelli and Rabino [65] have called the structural-cognitive modeling shift.

In fact, dynamic DSS are designed and developed in the literature using: (1) classical design methods, (2) system dynamics[1] approach [11], or (3) cognitive modeling methods. Few works are devoted to the development of KDD-based DSS (e.g. our works presented in [3] (based on the Unified Process/U model) and [54] (an extended version of the Unified Process)). Design considerations of visualization

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[1] System modeling and simulation tool.

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integration in the KDD-based DSS process are also suggested in [55]. However, there is no approach proposed in the literature for the visual KDD-based dynamic DSS cognitive modeling. So, in this research work, we wanted to explore the following interrogations: (1) "Which cognitive modeling approach should be followed to build a visual KDD-based dynamic DSS?" and (2) "Is it possible to take advantage of the existing cognitive modeling approaches?"

In this context, our goal is to propose a cognitive model that enables decision-makers to reason about their visual dynamic decision process based on the discovered knowledge from data. Our proposal consists in adapting the Hoc and Amalberti model [32] under the KDD specificities. To evaluate the proposed approach, its application was tested in the medical context to allow physicians (decision-makers) to fight against nosocomial infections in the Intensive Care Unit (ICU) of a hospital.

The remainder of this paper is organized as follows. Section 2 covers the theoretical foundations of our research, namely, the visual KDD-based Dynamic DSS and the cognitive modeling. Concerning section 3, it introduces a discussion about the proposed approach that models decision-making in the context of KDD. As for section 4, it provides a case study pertaining to KDD-based DSS visualizations which demonstrates how our cognitive modeling approach allows the decision-makers to follow up the ICU patient state and provide decisions. Regarding section 5, it provides an evaluation of the proposed and applied approach. Finally, section 6 presents the conclusion and suggestions for future work.

2. Related work

This section contains two parts, the first of which is a review of the literature to clarify the context of our research on the dynamic situations of a visual dynamic decision support system based on KDD. As for the second one, it briefly describes the characteristics of this type of situation as well as the cognitive requirements that the decision-maker may face.

2.1. Visual Dynamic DSS based on KDD

Time is increasingly taken into account in the implementation of decision support systems [8,63,79]. It has become a critical dimension in decision-making. Indeed, the expert makes a decision after analysis; the decision creates a result that affects the data; another decision must be taken, and so on. Actually, since the world is dynamic, DSS should be, too, and thus rises the interest in DSS.

The evolution of information technology has led to the availability of large volumes of data [6,7,30]. Therefore, the problem of the analysis of these data to extract information and knowledge to assist with decision-making has emerged [70]. Data mining has appeared as a solution to these problems. It does not consist only in extracting knowledge in the form of patterns but also in understanding the relationships between the data [20,22]. In fact, data mining refers to a central and crucial stage in a process known as KDD [50]. It is an interactive and iterative process that takes place following a series of stages. According to Cios et al. [14], the Knowledge Discovery Process (KDP) is a six-step model (see Fig. 1) [14,47]:

1) *Understanding of the problem domain* includes the problem and project goals definition, identifying current solutions to this problem, translating the project goals into data mining goals to initially select the data mining tools to be used later in the process.
2) *Understanding of the data* concerns collecting sample data and deciding which data to select according to their completeness and redundancy, missing values, etc. Finally, it is a question to verify the data usefulness with respect to the data mining goals.
3) *Preparation of the data* consists of deciding which data will be used as input for data mining methods. It includes data cleaning (check the completeness of data records, remove or correct for noise and missing values, etc.) and data transformation to reduce dimensionality (data discretization and granularization). The results are the data that meet the specific input requirements for the data mining tools selected in the previous step.
4) *Data mining*: it is the data miner that uses one or more data mining techniques to extract knowledge from prepared data.
5) *Evaluation of the discovered knowledge*: before proceeding to the knowledge integration, it is necessary to check if the models are novel and interesting to interpret them by an expert domain and evaluate the impact of the discovered knowledge.
6) *Use of the discovered knowledge*: it consists of the integration and the deployment of the discovered knowledge.

The arrows in Fig. 1 indicate the frequent dependencies between the steps of the KDP.

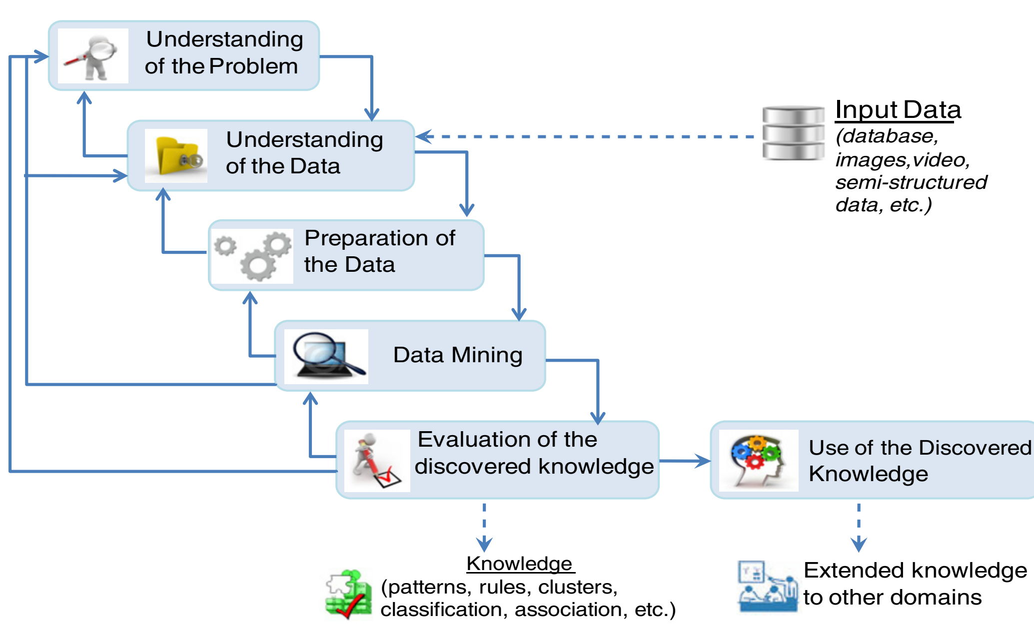

Fig. 1. The knowledge discovery process (adapted from [14]).