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Automatic construction of Fuzzy Inference Systems for computerized clinical guidelines and protocols

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ABSTRACT

Clinical guidelines and protocols (CGPs) are standard documents with the aim of helping practitioners in their daily work. Their computerization has received much attention in recent years, but it still presents some problems, mainly due to the low sustainability and low adaptability to changes (both in knowledge and technology) of the computerized CGPs. This paper presents an approach to an easy and automatic creation of Fuzzy Inference Systems (FISs), which are suitable for the computerized interpretation of differential diagnoses. The proposed FIS development process is based on applying Model-Driven Software Engineering techniques: automatic generation of computer artefacts and separation of concerns. The process focuses on the separation of roles during the design stage: domain experts use a basic editor that allows them to define the categories and factors that will be involved in the FIS in natural language, while knowledge engineers at a later stage refine these elements using a more advanced editor. The whole system has been tested by automatically generating two FISs that have been included in a computerized CGP for the diagnosis of a rare disease called hyperammonemia. This CGP has been validated and it is currently in use.

1. Introduction

CGPs are systematically developed statements intended to assist practitioners and patients with decisions about health care [1]. They describe the best clinical practices and, thus, reduce variations in health-care, improve effectiveness of diagnoses and therapies and discourage ineffective or potentially harmful interventions [2], because they are based on the best available scientific evidence and broad consensus.

However, CGP dissemination and knowledge transfer has not been successfully achieved [3]. In [4], authors point out that the transfer is ensured using Decision Support Systems (DSSs) in collaboration with Computerized CGPs (CCGPs). CCGPs provide access to the knowledge contained in CGPs and allow proposing timely patient-specific decision support and reminders [5].

CGPs usually consist of several elements, such as procedures, prescriptions and differential diagnoses (DDs). A DD is a diagnostic method used to identify, for example, a given disease from a set of alternatives based on symptoms and/or lab results. They are usually presented in a table, as that shown in Fig. 1. DD are very frequent in CGPs. Denekamp and Peleg [6] state that 12% of the CGPs included in the National Guideline Clearinghouse contain procedures that begin with a differential diagnosis. This percentage increases when considering CGPs that not only include DDs at the beginning. The sustainable computerization of DDs and their integration in CCGPs remains, nonetheless, an unsolved issue.

This computerization can be achieved by the use of FISs, which are often used in healthcare applications due to the ability of fuzzy variables to model both the uncertainty of diagnoses and the imprecision of symptoms [7]. One of their main advantages is that final users can understand their calculation process, instead of being black-box solutions.

However, as FISs are usually created from bibliography and expert advice, they require a far from negligible effort to be edited and updated. In this way, new methodologies are needed to overcome this problem. A Model-Driven Software Engineering (MDSE) approach can help in this process. The main objective of MDSE is to minimize manual programming by generating code automatically, thus avoiding problems that usually arise when developing software in a traditional manner [8].

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Differential diagnosis of suspected etiology				
	Gasometry (blood pH)	Ammonia (Normal < 110 μmol/L, Normal < 190 μg/dl, Children < 30 days)	Lactates (Normal < 2,5 mM, Normal < 20 mg/dl)	3-Hydroxybutyrate (Normal > 0,5 mM)
Disorders of ketogenesis	Very low	Normal or slightly high	Normal or slightly high	Low
Urea cycle disorders and/or intoxication by valproic acid administration	Normal or slightly high	Very high or critical	Normal or slightly high	Normal or slightly high
Maple Syrup Urine Disease	Normal	Normal or slightly high	Normal or slightly high	High

Fig. 1. Partial view of a DD table.

This paper presents a novel process to automatically generate FISs representing DDs taking advantage of MDSE techniques. The main contributions consist of (1) the development of a metamodel that gathers the knowledge necessary to represent a FIS, and (2) the use of MDSE techniques for the automatic generation of executable FISs after defining a FIS model. The resulting process has been tested by developing two FISs that have been integrated into a CCGP for the *Diagnosis and Treatment of Acute Hyperammonemia in Children* (DTAHC). This CCGP is intended to diagnose and treat children suffering from this rare metabolic disease. DTAHC CCGP has been developed using Aide Guideline Technology Platform (Aide-GTP) [9], a system that allows the computerization of CGPs and the execution of their corresponding CCGPs. The evaluation of this CCGP is endorsed by the Spanish Society of Metabolism Inborn Errors of the Spanish Paediatrics Association.

The next section introduces in detail the three pillars in which this work is based: Aide-GTP, MDSE and FISs. Then, Section 3 describes the development process of FISs. The developed FISs included in the CCGP for the DTAHC are also presented, as well as the proposed FIS metamodel and the FIS edition process. Section 4 briefly presents the results of this work, while Section 5 discusses those results and Section 6 finally points out the conclusions.

2. Background

2.1. Aide Guideline Technology Platform

Aide-GTP is a technology platform composed of Aide Development Suite (Aide-DS), a module for CCGP development and Aide Guideline Execution Platform (Aide-GEP), a module for CCGP execution (see Fig. 2).

Aide-GTP represents CCGPs following the Task Network Model (TNM) as defined by Peleg et al. [10], which is the paradigm used by the majority of the existing CCGP representation models. According to the TNM, a CCGP can be hierarchically decomposed in sets of basic clinical tasks that must be performed in a predefined order. In a lower level of abstraction, i.e. from the perspective of the actual implementation of the CCGP, these tasks can be organized in a graph-like structure, so nodes represent tasks that the user must perform and arcs between nodes specify the order in which these tasks must be carried out. Aide-GTP deals with six types of nodes: (1) question nodes let the system get information from the user during the execution of a CCGP; (2) action nodes ask the user to perform a particular task; (3) calculation nodes compute logical or mathematical expressions; (4) recommendation nodes show the user the result of certain calculations; (5) decision nodes determine the execution path by examining the answers provided by the user in question nodes and the results of the computations performed in calculation nodes; and (6) end-of-execution (or final) nodes indicate that the end of a CCGP has been reached.

Aide-Portal, formerly known as e-GuidesMed [11], is a web-based portal that interfaces with Aide-GEP. This portal is in charge of executing the CCGPs created using Aide-GTP. Aide-GEP connects with an external inference engine using web-services to execute those logical and mathematical expressions indicated in calculation nodes. Specifically, at this moment it executes statements in CLIPS modules [12] and FuzzyCLIPS [13], which are de facto languages for creating rule-based systems.

This paper focuses on Aide-DS, which is the authoring module that allows the development of CCGPs for their posterior deployment and execution in Aide-GEP. Aide-DS is formed by two edition modules [14]: Aide Medical Authoring Tool (Aide-MAT) and Aide Knowledge Authoring Tool (Aide-KAT). Aide-MAT offers a set of

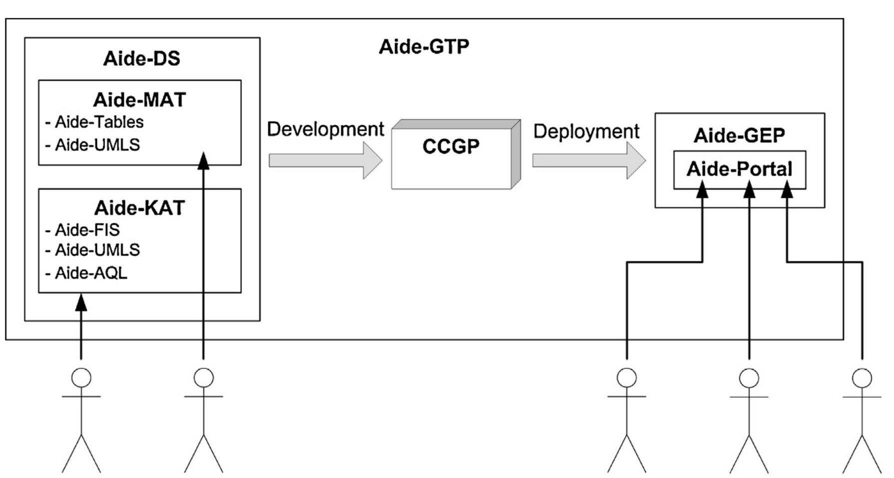

Fig. 2. Architecture of Aide-GTP technology.