Computational Argumentation-based Clinical Decision Support

Demonstration

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ABSTRACT

This demonstration highlights the design of the Consult system, a modular decision-support system (DSS) intended to help patients suffering from chronic conditions self-manage their treatments. The system takes input from multiple sources, including commercial wellness sensors and a patient's electronic health record, to inform a *computational argumentation* engine that constructs weighted opinions using these inputs and knowledge about their sources, and uses an interaction agent driven by *argumentation-based dialogue* to respond to user queries.

KEYWORDS

Argumentation; Human-agent interaction; Decision-support tool

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1 INTRODUCTION

The Consult (Collaborative mObile decisioN Support for managing mULtiple morbidiTies) project explores the feasibility of employing a collaborative decision-support system (DSS) to help patients suffering from chronic diseases self-manage their treatments. The Consult system exhibits the following key properties: (1) integration of data from multiple sources, including commercial wellness sensors, a patient's *Electronic Health Record (EHR)*, input from *Health Care Professionals (HCPs)* and treatment guidelines, to produce an adaptive care plan customised to the patient's current circumstances; (2) application of *computational argumentation* and *provenance* to structure and track the data from these disparate sources, and to identify reinforcing and conflicting information; and (3) interaction with patients via *argumentation-based dialogue* to ensure understanding of the information gathered in (1) and to address, and potentially resolve, any conflicts found in (2).

Research has established that involving patients in the management of their own disease has long-term health benefits [9]. Advances in commercial wireless sensor technology mean that it is practical for patients to monitor a wide range of health and wellness data at home, including blood pressure and heart function, without direct supervision by medical personnel.

However, currently such sensor data is disconnected from a patient's EHR and personalised treatment plan (constructed in conjunction with an HCP); treatment plans do not adapt dynamically to changes in patient circumstances; and a record of patient decisions about and responses to daily care is not routinely captured in a standardised way, preventing learning about treatment effectiveness from such a record. The long-term and overarching aim of the Consult project is address these issues.

Our approach is founded on the use of *computational argumentation* to model relationships between elements of information, represented as logic predicates, and the sources of that information, tracked using *data provenance.* Argumentation [5, 14] is a well-founded formal methodology with roots in philosophy and has been applied in *artificial intelligence (AI)* and *multi-agent systems (MAS)* as a structured technique for reasoning where conclusions are drawn by analysing evidence that supports (or refutes) the conclusions. Different from model-driven and other formal systems, argumentation-based systems have the ability to explain why a decision was made in a particular context. Further, argumentation-based systems can incorporate models of *trust* [15], *data provenance* [4] and user preferences to modulate reasoning.

2 THE CONSULT SYSTEM

Our computational argumentation engine is combined with a number of other components in order to form the Consult system, shown in Figure 1. We aim to realise each of these components as self-contained *RESTful microservices* [6, 11], providing advantages with respect to scalability, resilience and composability. These components (services) interact in order to support patients using the Consult system. To illustrate the role of each of these components, and the way in which they interact, we consider the following support scenario.

Running Example. Joy is a 54-year old female who has suffered a stroke; she is prescribed *angiotensin-converting enzyme (ACE) inhibitor* [13]. Joy started taking *ibuprofen* after experiencing back pain. After a few days, the Consult system detects that this has caused an increase in her blood pressure. Can the Consult system help Joy to choose a different treatment?

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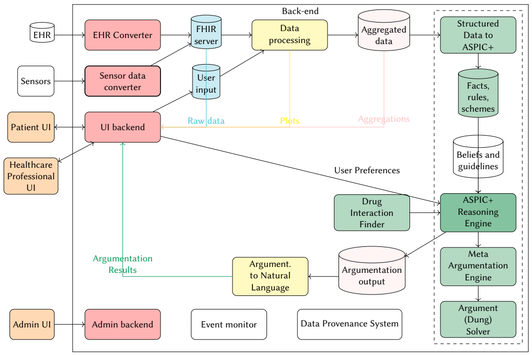

Figure 1: Consult system architecture.

2.1 Argumentation-based Reasoning for Supporting Medical Decisions

The Consult system detects the increase in blood pressure using a wellness sensor, which Joy wears. This sensor exists as a part of the front-end layer in our architecture and provides biometric data as input to the system (Figure 1), which in this case is Joy's blood pressure. In order to facilitate access to a patient's medical history, should the Consult system require it, Joy's EHR also exists as an input. In order to detect Joy's blood pressure exacerbation, the data collected from her wellness sensor (and, if relevant, her EHR), is first converted into a standard format for use by the rest of the system (red blocks), and stored for processing (blue block). This format is as a set of *Fast Healthcare Interoperability Resources (FHIR)* [1]. This is done using a bespoke translation tool [3]. Joy's sensor data is then mined (yellow block) in order to identify her elevated blood pressure level.

Once an abnormality, such as high blood pressure, is identified, the data miner invokes the argumentation engine (green blocks) in order to assist Joy in deciding what to do. The argumentation engine uses data aggregated by the miner (pink block) to instantiate argument schemes and attack schemes in a metalevel argumentation framework [7, 10, 16], and it constructs arguments and attacks to recommend a different treatment for Joy. During the reasoning process, the argumentation engine also leverages clinical guidelines. For example, the guidelines found in the NHS Choices leaflet [12] are represented using first order logic [8]. Using this information, the argumentation engine can recommend alternative treatments to reduce Joy's back pain. We also consider conflicts that may arise as a result of combining multiple guidelines. Zamborlini *et al.* [17] introduce a semantic representation and logical reasoner to detect interactions among recommendations by combining various guidelines. We encapsulate this representation and reasoner in an external set of services, defined according to a guideline microservice architecture [2], in order to integrate their work into the Consult system (*Drug Interaction Finder* in Figure 1). Therefore, the argumentation engine invokes the *Drug Interaction Finder* service to get information about the possible contradictions among drugs before making any recommendation. In the case of Joy's elevated blood pressure, given the available clinical guideline knowledge, and knowing that Joy is already taking *ibuprofen* which is the cause of this anomaly, the argumentation engine recommends that Joy consider *paracetamol* or *codeine* instead of *ibuprofen*.

2.2 User Interaction with the Dialogue Agent

As there are different side effects to taking each of these drugs, the aim now is for the Consult system to engage Joy in an argumentation-based dialogue to determine which drug she should take. To do this, the output of the computational argumentation process (the recommended drugs and their side effects) is stored (pink block), before being translated into natural language (yellow block) and communicated back to Joy via a User Interface (UI) backend, which supports two methods of patient interaction. This first is a web *dashboard*, as illustrated in Figure 2, where Joy can view and respond to these options, as well as general information, such as the data collected by her wellness sensor(s) and summarised data from her EHR. The second is an interactive agent, implemented via a *chatbot* style interface. Joy can be prompted by this agent to adjust her medication and confirm her choice, or, more generally, proactively talk to the agent in order to ask a range of questions, for example, requesting *explanations* about the data in her dashboard or receiving recommendations for undertaking activities such as walking or cycling (see https://youtu.be/e7-juzLn9b8).

Using one of these methods, Joy selects an alternative drug—*paracetamol* or *codeine*—and this is communicated back to the system as a user preference, and stored for future reasoning and recorded in their EHR. Note also that while, in this scenario, Joy, as a patient, is interacting with the system for the purpose of self-management, the system is also designed to interface with two other types of users: HCPs, for longitudinal tracking of symptoms and behaviours and for making treatment recommendations; and system administrators.

3 SUMMARY

The Consult system aims to support stroke patients in the self-management of treatments. This is accomplished using argumentation and provenance to reason over data from multiple sources, and structured dialogue to exchange information with users.

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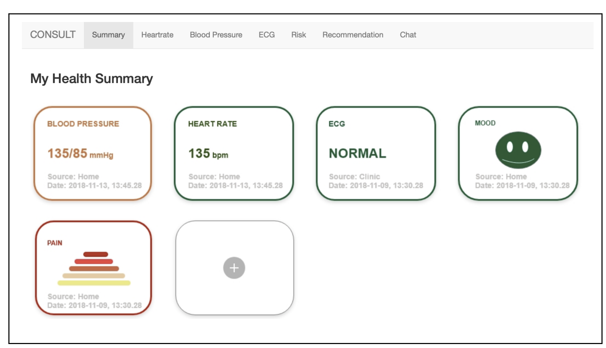

Figure 2: An example design for the Consult dashboard

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