Towards Argumentation-based Recommendations for Personalised Patient Empowerment

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ABSTRACT
Patient empowerment is a key issue in healthcare. Approaches to increase patient empowerment encompass patient self-management programs. In this paper we present ArgoRec, a recommender system that exploits argumentation for leveraging explanatory power and natural language interactions so as to improve patients’ user experience and quality of recommendations. ArgoRec is part of a great effort concerned with supporting complex chronic patients in, for instance, their daily activities after hospitalisation, pursued within the CONNECARE project by following a co-design approach to define a comprehensive Self-Management System.

CCS CONCEPTS
• Applied computing → Consumer health: Health care information systems; • Information systems → Expert systems; • Human-centered computing → Ubiquitous and mobile computing systems and tools; • Computing methodologies → Discourse, dialogue and pragmatics; Multi-agent systems;

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1 INTRODUCTION
Patient empowerment is a key issue in current healthcare that should be seen as both an individual and a community process. Four components are fundamental to the process: (i) understanding by the patient of her/his role; (ii) acquisition by patients of sufficient knowledge to be able to engage with their healthcare provider(s); (iii) patient skills; and (iv) a facilitating environment [1]. Although the idea of patient empowerment was introduced to healthcare in the 1970s [20], its popularity emerged in the mid 1990s [18], and became a feasible reality only in 2000s thanks to the advent of Web 2.0 [5]. In general, strategies to increase patient empowerment address two aspects of patients’ experience [19]: (i) disease management and (ii) relationships with healthcare providers. Approaches to increase patient empowerment vary from patient self-management programs [16], to promoting patient involvement in treatment decision-making [13], to facilitating the physician-patient interaction [17].

In this paper, we present a recommender system named ArgoRec, which is part of the great effort for providing support to complex chronic patients pursued by the CONNECARE project [23], by following a co-design approach. ArgoRec distinctive feature is that it relies on argumentation to provide justifiable and personalised recommendations, increasing accuracy of recommendations based on continuously monitored data while improving patients’ user experience. Current commercial solutions, in fact, aim to keep patients autonomous by providing them with wearable, non-intrusive devices (e.g., wristbands and medical devices), paired with proprietary smartphone apps. Nevertheless, recommendations are predefined by providers and usually cannot be personalised. On the contrary, clinicians interested in monitoring activities, health-status, and possibly habits, prefer to set the goals to be achieved by each patient (e.g., number of steps per day) and expect the system to generate tailored recommendations accordingly—as ArgoRec does.

The rest of the paper is organised as follows. In Section 2 a minimal and necessary background on argumentation is given. Section 3 presents the proposed model and its architectural design. Section 4 discusses the benefits and challenges stemming from preliminary results. Section 5 ends the paper with final remarks and future directions.

2 ON ARGUMENTATION
Argumentation is amongst the most natural ways people interact through dialogue [22]: people argue by making claims, attack others’ ones, and provide further premises for supporting own ones, with the goal of winning a debate. Computational argumentation is a research thread concerned with designing computational models and algorithms to analyse and construct arguments and their relationships with the aim of enabling automatic reasoning over acceptability of arguments [15].

In abstract argumentation arguments are considered as atomic units and the only considered relation is the attack one, meaning...
arguments are in conflict [8], whereas in structured argumentation arguments may be constituted by claims ("what to be proven true") and premises ("what helps proving something true"), and relations amongst them also encompass the support one, linking premises to claims [4]. Moreover, attack relations are further divided into rebuttal, in case two claims clash, and undercut, when a claim contrasts the premise of the attacked claim.

Many different argumentation frameworks exist, extending the notion of argument or relation, or both. For instance, weighted [9] and value-based [3] frameworks attach quantitative labels to relations to express, respectively, strength of arguments over others. These kind of schemes are especially useful in those open and highly dynamic scenarios in which the relevance of arguments is likely to change over time, i.e., due to acquisition of new information.

In this paper, we exploit argumentation for (i) empowering recommendation systems with explanatory power regarding why and how recommendations are provided, and (ii) improve patients’ user experience through natural language interactions—as discussed in Section 3. In particular, we adopt the simple structured argumentation framework depicted in Figure 1 as an argumentation graph, where darker nodes are claims whereas lighter ones are premises and shaded boxes are whole arguments, solid arrows are attack relations whereas dashed ones are support ones – darker ones are rebuttals and lighter ones are undercuts –, and the thickness of lines represents the strength of the relation. This serves well the purpose of discussing the benefits and challenges of argumentation based recommendations (Section 4), while keeping the paper accessible to readers unfamiliar with process algebraic descriptions of argumentation frameworks’ semantics.

Although the idea of using argumentation to improve recommendations is not novel [2, 6], to the best of our knowledge this is the first attempt to exploit it in healthcare.

3 SYSTEM MODEL & ARCHITECTURE
This section presents our Argumentation-based Recommender system, ArgoRec, by first describing its model & inner functioning (Subsection 3.1), and then discussing the architecture of the overall self-management ecosystem it is part of (Subsection 3.2).

3.1 System Model
ArgoRec revolves around the following main abstractions:

prescription any kind of prescription made by a clinician to a given patient to monitor, e.g., physical activities, health status through medical devices and/or suitable questionnaires, taking medications, and so on.

adherence the adherence of the patient to the clinician’s prescriptions, both regarding individual prescriptions (adherence level) and their history based on a given time window (adherence profile).

fulfillment the fulfillment of a prescription achieved by the patient, necessary to measure the patient’s adherence—either automatically (e.g., through an activity tracker) or manually (e.g., by the patient her/him-self tracking taken tablets).

recommendation the message to dispatch to the patient for engagement, reward, or warning, depending on her/his adherence, or the one to be sent to the clinician for continuous follow-up (in this case, it’s called feedback). According to the corresponding adherence, recommendations may have a punctuation from 1 (“very bad”) to 5 (“very good”), thus messages sent accordingly: an alert for low punctuation (e.g., “You’ve to be more active. Go out and take a walk!”) and a reward for a high one (e.g., “Wonderful! Walk 100 steps more and you’ll reach the goal!”).

strategy the criteria guiding decision making about how to compute the adherence, and which recommendation/feedback to send, when.

recommendation engine the component responsible of generating and dispatching recommendations and feedbacks, based on the patients’ adherence regarding their fulfillment of prescriptions, and on a dynamically configurable strategy.

In ArgoRec, recommendations and feedback are interpreted as arguments, whose claims (i.e. the fact that the patient is doing well or not) are supported by premises constituted by the patient’s adherence. The strength of support relations is dynamically computed (and adjusted), and depends on the time window that the adherence of the patient refers to: recent activity events (that is, fulfillment to more recent prescriptions) are stronger premises with respect to more ancient events. Accordingly, attack relations between arguments are possible because the recommendation engine may be tempted to generate conflicting recommendations based on different time windows, i.e., focusing on the adherence level (memoryless) versus the adherence profile (historical). In this case, argumentation helps ArgoRec to generate the most correct recommendation (or feedback), by exploiting argumentation-based reasoning to select the stronger claim—that is, the one supported by the strongest premises. Figure 1 depicts an example argumentation graph in which recommendation “keep going” is the strongest argument, thus gets generated and dispatched. Essentially, despite comparison of latest fulfillment event (fulfillment\textsubscript{i,t}) with previous one (fulfillment\textsubscript{i,t-1}) suggests to warn the patient about the need for improvement (recommendation “must improve”) – since her/his adherence is worsening –, the fact that there is still time left to complete prescription (prescription\textsubscript{i}) steers arguments’ strength in favour of recommendation “keep going”, to further motivate the patient.

Besides correctness, this way ArgoRec can, on the one hand, provide to patients more convincing recommendation messages, by motivating and explaining the reasons behind them (the why) and, on the other hand, provide to clinicians insights on the decision making process leading to that precise feedback (the how). Both can

![Figure 1: Example of argumentation graph exploited by ArgoRec.](image-url)
be achieved by navigating the argumentation (sub)graph whose
claim is the recommendation or feedback itself to, for instance, gen-
erate explanation sentences through Natural Language Processing
(NLP) techniques and argumentation mining—as better discussed in
Subsection 4.1.

To deliver its functionalities, ArgoRec works as follows (see
also Figure 2). Whenever an activity fulfillment event is received:
(i) it is checked against the corresponding prescription to compute
adherence level of the patient and update her/his adherence profile,
depending on the configured strategy (i.e. defining how to weight
er older vs. newer events); (ii) new arguments are generated accord-
ingly and added to ArgoRec argumentation graph (i.e., an “halfway”
fulfillment may support a “keep going” recommendation); and (iii)
weights of relations are updated depending on the newly-added ar-
guments (i.e. new premises for a claim increasing support strength)
and ArgoRec’s own strategy (i.e. decreasing strength of arguments
as time flows). Finally, periodically and depending on the config-
ured policies, ArgoRec generates recommendations and feedback
based on the strongest argument(s) in the graph—i.e. navigating
the graph to generate sentences through NLP.

3.2 System Architecture

ArgoRec is part of a Self-Management System (SMS) developed
within the CONNECARE project and aimed at monitoring patients
habits in terms of physical activities, health status, taking medica-
tions, as well as nutrition. It consists of, among others, an app
for the patient to receive messages (i.e., tasks and appointment
requests), set which activities to monitor depending on clinician’s
prescription, accept or decline a request sharing certain parts of
her/his data with a specific clinician, and keep a calendar for tasks
and appointments.

The clinician makes the prescription of each habit to be mon-
tored (i.e., how many steps per day, which and how many pills
to take, and which health variable to measure and with which fre-
quency) through a dedicated web-based application, in which a case
may be defined according to the corresponding clinical pathway,
the set of prescriptions to be sent to the SMS, and the clinicians
involved in follow-up of the case. Figure 2 sketches the overall flow
of data. The clinician prescribes an activity, the patient receives
it through the SMS smartphone app, then performs the activity;
the patient’s wristband monitors the activity, sends data to the
smartphone, which are then sent to “the cloud” in which ArgoRec
lives together with the SMS back-end, analysing data and sending
recommendations and feedback. Let us note that how the SMS and
the web application interact is out of the scope of this paper.

4 KEY BENEFITS & CHALLENGES

Experiments with ArgoRec just started with healthy-volunteers
in Catalonia. Volunteers were asked to wear a Fitbit charge HR and
to perform their normal activity. In a first period they will be using
ArgoRec with the argumentation capability turned off, then it will
be turned on. Patients’ improvement rate in the two periods will be
measured, as well as efficacy of recommendations—i.e. in terms of
short-term changes in patients behaviour. This will serve as a first
indication of whether argumentation helps motivating patients.

In this Section we briefly summarise the key benefits that we en-
visage in using the proposed recommender system (Subsection 4.1)
as well as the challenges to be faced by the SMS and ArgoRec for
deployment in production (Subsection 4.2)1.

4.1 Key Benefits

Argumentation may play a crucial role in dealing with the fear of
algocracy [7], that is, of having our everyday life influenced by some
form of opaque algorithmic decision making, we have no control on
nor clue about its inner functioning. This is very relevant in case
of recommendations for patients that suffer of chronic illness and
that are, usually, elderly. In fact, clinicians need to have control on
the feedback given to patients to avoid self-defeating messages that
may affect patients and/or do not fit with the real needs of a given
patient. This motivates the need for moving from black-box to grey-
box algorithms, lending themselves to (at least, partial) inspection
and interpretability by human users. In this respect, argumentation
straightforwardly enables algorithms to explain and justify decision
making—both to patients and clinicians.

This may happen, for instance, by integrating argumentation
with NLP techniques to generate explanatory sentences [10]. Ac-
cordingly, NLP may prove to be invaluable especially in healthcare-
related scenarios involving chronic patients and/or elderly people,
who may be much more accustomed to interact with other people
(thus, through oral communication) than with technology (that is,
through GUI or gestures) [14].

Argumentation also brings along an interesting opportunity
regarding autonomous learning of recommendation rules, that is, the
criteria upon which recommendations are provided to the patient.
In fact, pattern mining techniques are already proficiently employed
in many applications of the IoT, where they enable associated rule
In this respect, statistical relational learning [12] is a promising
source of solutions, since it merges logic with probabilistic models to
detect correlations between data despite uncertainty of perceptions,

1Clinical studies will start at the end of 2017 in 4 sites: Barcelona, Lleida, Groningen,
and Israel.
while exploiting background knowledge to provide explanations about the learning process itself—i.e., why and how a given rule has been inferred.

4.2 Challenges

Despite argumentation being an active field of research for so long, most of the fundamental results achieved are theoretical. Being interested in applying argumentation in a recommender system to empower complex chronic patients, we move from a theoretical perspective to the real-world. It is worth noting that the main challenge is moving from a technical perspective (such as finding the best logic frameworks) to an organisational and social change in case management for both patients and clinicians. In fact, on the one hand, patients have to learn how to interact with suitable devices (i.e., wristband and smartphone or wireless medical devices) and they have to be confident about the recommendations they receive. On the other hand, clinicians have to receive the right information (grey-box approach) to trust the recommendations automatically generated. What may happen is that, if not correctly motivated, patients stop to use the self-management system and clinicians interrupt prescription of activities through the SMS or checking of the received feedback due to the lack of trust and transparency of decision making.

5 CONCLUSIONS & FUTURE WORK

In this paper, we presented the model and architecture of ArgoRec, a novel kind of recommender system that relies on argumentation to provide suitable information (rewards, alerts, feedback) to patients and clinicians in natural language. ArgoRec has the potential to sensibly improve patients’ engagement as well as clinicians insights into decision-making of recommender systems.

To substantiate our claim, we just started the evaluation of a first proof-of-concept prototype of ArgoRec. The prototype will be used by healthy volunteers in Catalonia during the summer to monitor physical activity (i.e., performed number of steps). According to the underlying co-design approach, recommendations will be analyzed by the users as well as by clinicians from Hospital Santa Maria in Lleida (Catalonia, Spain). The corresponding feedback will be used to improve the system and get it ready to be used in the CONNECARE project with patients from Barcelona, Lleida, Groningen and Israel. In particular, two case studies will be considered: (1) Community-based management of complex chronic patients, and (2) Preventive patient-centered intervention in complex chronic patients undergoing elective major surgical procedures.

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