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Using argumentation to manage users' preferences

C.L. Oguego [a], J.C. Augusto [a,*], A. Muñoz [b], M. Springett [a]

[a] Department of Computer Science, Middlesex University London, UK
[b] Department of Polytechnic Sciences, Universidad Católica San Antonio de Murcia, Spain

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ABSTRACT

Argumentation has provided a means to deal with inconsistent knowledge. We explore the potential of argumentation to handle conflicting user preferences. Classical preference handling methods in Artificial Intelligence (AI) lack the ability to handle ambiguity and the evolution of preferences over time. Previous experiments conducted by the authors indicate the usefulness of argumentation systems to handle Ambient Intelligence (AmI) examples with the aforementioned characteristics.

This paper explores a generalized framework that can be applied to handle user preferences in AmI. The paper provides an overall preference handling architecture which can be used to extend current argumentation systems. We show how the proposed system can handle multiple users with the introduction of personalized preference functions. We illustrate how user preferences can be handled in realistic ways in AmI environments (such as smart homes), by showing how the system can make decisions based on inhabitants' preferences on lighting, healthy eating and leisure.

1. Introduction

One of the key factors in designing a successful Ambient Intelligence (AmI) system is the balancing of users' preferences [1,2]. This is particularly important in Ambient Assisted Living (AAL) [3]. AAL systems rely on sensing technology deployed in a physical space to gather real time contextual information, which the system uses in decision-making to benefit the users of that space. On a daily basis we enter sensorised spaces such as cars and homes and we also bring sensors with us in our smart phones. Examples of current wireless sensors are Passive Infrared Sensors (PIR) which allow tracking of movement within a room and pressure sensors to sense whether someone is in bed or sitting on a chair. There are sensors which allow controlling lights knowing when they are on or off and also actuators turning them on or off. There is now a wide range of devices, including wearables, which can provide data from an individual's vital signs, e.g. blood pressure and glucose levels, and this information is available in digital form. Also important is the information that can be gathered from the outside world. So for example, public transport timetables, doctor appointments and supermarket offers may also help the system to support a human's life in a practical way. However, these systems cannot handle users' preferences in a dynamic way, and this is the focus of our paper. When a system is expected to act on behalf of humans, it needs to understand and respond to the preferences of users and should have the ability to resolve conflicting preferences.

Preferences are not only significant in making decisions for users in AmI, but also vital in understanding and supporting decisions made by users [1]. Evidence from [4] illustrates how preferences guide the choices of the user, and how preferences have a number of complexities that clash or produce conflicts. For example, listening to the radio or watching movies might change the user's opinion about a product, and make the user want more or less of the product.

Various preference handling models have been proposed in Artificial Intelligence (AI) to address preference recommendation problems. These techniques are not well equipped to reason and represent changes in users' preferences over time, nor do they deal with inconsistent preferences. Some of the prominent techniques are: Conditional Preference Network (CP-nets) [5], Utility Conditional Preference Network (UCP-nets) [6], Tradeoffs-Enhanced Conditional Preference Networks (TCP-nets) [7], Linguistic Conditional Preference Network (LCP-nets) [8].

These techniques in AI have been investigated because they closely relate to the problem we address in our research. However, our research aims to address preferences in AmI systems, and that requires methods which can cope with conflicting knowledge and reason with time.

Additional findings identified other relevant proposed techniques in the state of art. For example, [9] formalizes a problem of multiple criteria decision making within a logical argumentation system, designing a logical machinery that manipulates directly

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[*] Corresponding author.
E-mail address: J.Augusto@mdx.ac.uk (J.C. Augusto).

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arguments with their strengths and returns preferred decisions, enabling users to compute with justification preferred decision choices. Following the same line of research, an argumentation framework was presented by [10], to reason about qualitative interest-based preferences. The same authors further presented an argumentation-based framework [11] to model and automate reasoning of multi-attribute preferences of a qualitative nature, showing how to reason about preferences when incomplete or uncertain. A perspective on practical reasoning was proposed in [12] as probable justification for a course of action. This was based on an argumentation scheme, to support decision making processes in multi-agent systems. Collaborative research conducted by a computer scientist and a psychologist [13], presented seven procedures to help choose among options represented as bipolar set of arguments after its evaluation and ranked according to their importance. The authors of [14] employed multi attribute decision theory, and introduced several argumentation schemes, in order to provide an agent the best decision based on it preferences over outcome. However, these studies still are unable to manage preferences over time.

Our experience in the development of AmI systems enables us to conclude that argumentation is a technique that will provide advantages that the classical preferences in AI do not. Argumentation is basically concerned with the exchange of proposals and their justification [15]. These sets of arguments may either come from dialogue between several agents or from available pieces of information (which may be contradictory) at the disposal of one unique agent.

Argumentation develops as a reasoning process [16] that can help to make decisions by handling conflicting situations expressed within a discussion among participants (or agents) with different goals. During the 80's, argumentation started to attract attention within Computer Science (CS) as a branch of AI focused on ways to represent processes humans follow when using common sense reasoning, taking into account the influx of new information [17,18]. Time has also been an important matter in various areas of CS and AI [19] and in particular in AmI [20,21].

This paper presents a generalized framework that can be applied to handle users' preferences in an AmI environment by extending current argumentation systems. Section 2 discusses argumentation and its significance in handling conflicts and time. Section 3 complements argumentation with a general preference architecture, to show how argumentation can handle multiple users' preferences through personalized preference functions. We illustrate in Section 4 how users' preferences can be handled in AmI environments (such as smart homes) with realistic examples based on inhabitants' preferences on lighting, healthy eating and leisure. Section 5 provides conclusions and discussions on further work.

2. Temporal argumentation

The previous section provided a list of several theoretical methods which to some extent address the role of preferences in decision-making. However, from the point of view of Ambient Intelligence there are some further dimensions which are not explicitly addressed by those methods. Preferences sometimes are in conflict with each other. For example, sometimes there may be reasons to keep the lights on and also reasons to keep them off. Time also plays an important practical role, in particular preferences changing over time. For example, we prefer different levels of lighting at night or day and through different seasons we prefer different ambient temperatures. Computer Science has long investigated both these features of handling conflicts and time handling in Argumentation Systems [21–24]. We believe time-based argumentation is an option worth exploring, offering advantages that the methods in the previous section could not. We use this section to introduce some basics of argumentation, and in particular temporal argumentation. We later show with example scenarios how desirable features in AmI are more naturally captured by the Argumentation System we describe.

The basic idea of argumentation is to create arguments in favour of and against a statement in order to determine if that statement can be acceptable or not and why. Amongst other features argumentation offers a way to represent defeasible reasoning, characterizing the skill that allows us to reason about a changing world where available information is incomplete, or not very reliable. Argumentation systems have the ability to change conclusions in response to new information that comes to the system. The conclusions obtained by the system are "justified" through arguments supporting their consideration. In addition, an argument could be seen as a "defeasible proof" for a conclusion. The knowledge of new facts can lead to a change in preference, or to consider a previous inference no longer correct. In particular, there could exist an argument for a conclusion C and a "counter-argument", contradicting in some way the argument for C. An argument is a valid justification for a conclusion C if it is better than any other counter-argument for C. To establish the preference of an argument over the others, a definition of preference criteria is required. Several preference methods are possible, and one of the more widely used is "specificity" [25], favouring more specific information, i.e. better informed arguments. It is important to highlight that Argumentation Systems emphasize the role of inference justification and the dialectical process related to reasoning activities.

Given the limitations we have noticed in the handling of preferences by state of the art systems, including both handling of inconsistency and time-related information, we will use an Argumentation System which allows us to explicitly refer to time [26]. We refer the reader to the original article for a detailed description of the underlying theoretical framework. Here we provide only a short overview of the notation that is required to understand the description of the scenarios later in our article.

The system $\mathbb{L}(\mathbb{T})$ presented in [26] is actually an extension of *MTDR*, a previous well-known argumentation framework [27]. The extension includes addition of a temporal language $\mathcal{L}^{\mathbb{T}}$. This temporal language allows reification over time, properties, events and actions, which have been considered in the AI literature as key concepts to model a rational agent in a dynamic world. The system used to represent knowledge is based on a many-sorted logic [28], where different sorts are used to formalize the different concepts represented in the system. The fundamental building blocks such as time, properties, events and actions listed above are only examples of possible sorts. Others can be added depending on need. We do so in Section 3.

The temporal language allows association of knowledge to either "instants" ($\mathcal{T}$) or "intervals" ($\mathcal{I}$) so that we can express developments in real-world scenarios that happen (or are perceived to happen) instantaneously as well as developments requiring a non-atomic duration to complete. An example of an instant could be something that happened in a second in a system where seconds are the minimum time granularity, and an example of an interval will be a whole minute in that system. So if a Passive Infrared Sensor (PIR) is triggered only once in a second, e.g. at 17:06 PM, then we can describe that as an instantaneous occurrence. If the same sensor is activated continuously for 15 s we can say that the activation of the sensor lasted for a while and those 15 s will become an interval of time, e.g. from 17:06 PM to 17:21 PM. We can define familiar order relationships between units of time. So for example the following relationship between instants represents the notion of 'earlier time' $<: \mathcal{T} \times \mathcal{T}$ such that we can say 17:06 PM $<$ 17:21 PM. We can also define the notion of interval as a sequence of consecutive instants $\mathcal{I} = \{[i_1, i_2] \in \mathcal{T} \times \mathcal{T} | i_1 < i_2\}$ so that, for example, [17:06 PM, 17:21 PM] can be the interval where the sensor