

Using Argumentation to Manage Users' Preferences

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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 personalised 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.

Keywords: Users' Preference, Preference Handling, Ambient Intelligence, Argumentation, User-centric Computing, Ambient Assisted Living

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

can not 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] formalises a problem of multiple criteria decision making within a logical argumentation system, designing a logical machinery that manipulates directly 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 its 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 im-

portant 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 personalised 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, 22, 23, 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 17:06PM, then we can describe that as an instantaneous occurrence. If the same sensor is activated continuously for 15 seconds we can

say that the activation of the sensor lasted for a while and those 15 seconds will become an interval of time, e.g. from 17:06PM to 17:21PM. 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 17:06PM $<$ 17:21PM. We can also define the notion of interval as a sequence of consecutive instants $\mathcal{I} = \{[i_1, i_2] \in \mathcal{T} \times \mathcal{T} \mid i_1 < i_2\}$ so that, for example, [17:06PM, 17:21PM] can be the interval where the sensor was continuously active. Auxiliary useful functions like $begin, end : \mathcal{I} \rightarrow \mathcal{T}$ can be defined to obtain the beginning and ending points of an interval: $begin([i_1, i_2]) =_{def} i_1$ and $end([i_1, i_2]) =_{def} i_2$. We will consider a set of well-known relations in the literature as those between intervals initially explored by Hamblin [29] and later adopted by Allen [30].

We assume the world can be described as a set of elements or entities with specific properties, for which we will use the following predicate: $Hold_{at}(p, i)$, $Hold_{at} \subseteq \mathcal{P} \times \mathcal{T}$, and $Hold_{on}(p, I)$, $Hold_{on} \subseteq \mathcal{P} \times \mathcal{I}$, denoting that p is a property that is true in the moment i or interval I respectively. $Hold_{on}$ and $Hold_{at}$ are related in the following way:

$$Hold_{on}(p, I) =_{def} \forall_{\mathcal{T}} i (In(i, I) \rightarrow Hold_{at}(p, i))$$

We will assume “homogeneity” of properties over an interval, meaning that if a property holds in an interval then it also holds in any of its subintervals. For example, if a sensor was activated for 15 minutes in a row, in particular it was activated in each minute of that interval (and each second of each minute):

$$\forall_{\mathcal{T}} i \forall_{\mathcal{I}} I (Hold_{on}(p, I) \wedge In(i, I) \rightarrow Hold_{at}(p, i))$$

$$\forall_{\mathcal{I}} I, I' (Hold_{on}(p, I) \wedge I' \sqsubseteq I \rightarrow Hold_{on}(p, I'))$$

We consider “weak negation” of properties over intervals that can be obtained directly from the negation of the previous definition:

$$\neg Hold_{on}(p, I) =_{def} \exists_{\mathcal{T}} i (In(i, I) \wedge \neg Hold_{at}(p, i))$$

We will consider events as noticeable occurrences of the real world that can have an effect on a given situation. For example, the system sending a command to the light causes it to light up the room. We will use a predicate $Occurs_{at}(e, i)$ ($Occurs_{on}(e, I)$) to indicate that an event e has occurred in an instant i (interval I), for example: $Occurs_{at}(TurnOnLight, 7:00:05AM)$, ($Occurs_{on}(Microwavecooling, [16:10:05, 16:12:35])$). Mirroring explicit time references through instants and

intervals, we assume non-durative and durative events defined in sorts \mathcal{N} and \mathcal{D} respectively.

We will assume the following about event instances: $\text{Occurs}_{on}(e, I) =_{def} \forall_{\mathcal{T}} i (\text{In}(i, I) \rightarrow \neg \text{Occurs}_{at}(e, i))$ with $\text{In}(i, I) =_{def} \text{Start}(i, I) \vee \text{Divides}(i, I) \vee \text{Ends}(i, I)$ where these three predicates are true when an instant is at the beginning, ‘inside’, or the end of an interval. The definition given above for $\text{Occurs}_{on}(e, I)$ means the occurrence of a specific event in an interval implies it does not occur inside the interval (this is usually called “non-homogeneity”). We consider “weak negation” over durative events. That is, consequently with the concept of non-homogeneity explained above, an event will be considered not to have occurred if a fragment (even just an instant) of it has not occurred.

We will ascribe actions only to humans, so humans usually acting on their free will perform actions which typically cause some events to occur which in turn potentially change some properties of the world. We will consider that each human agent a from the sort of agents \mathcal{A} has a repertoire \mathcal{W} of possible actions g : $\forall_{\mathcal{A}} a \exists_{\mathcal{W}} g \text{Agent}(a, g)$. There could be instantaneous actions Do_{at} (e.g. switching the light on) and durative actions Do_{on} (e.g. getting up from bed).

The explanations above mostly refer to the time related representation of the world. Now we turn focus more properly to inconsistency handling through the argumentation system. That is how information about a dynamic world can be grouped together to form arguments.

We will assume our knowledge base is composed of a non-defeasible knowledge part $\mathcal{K}^{\mathbb{T}}$ which in turn is organized in two subsets, one set of facts $\mathcal{K}_G^{\mathbb{T}}$ (general knowledge) and one set of rules $\mathcal{K}_P^{\mathbb{T}}$ (particular knowledge), where $\mathcal{K}_P^{\mathbb{T}} \cup \mathcal{K}_G^{\mathbb{T}} = \mathcal{K}^{\mathbb{T}}$ and $\mathcal{K}_P^{\mathbb{T}} \cap \mathcal{K}_G^{\mathbb{T}} = \emptyset$. $\mathcal{K}_P^{\mathbb{T}}$ represents the safe facts of the world such as the existence of a specific bedroom in a specific house and a week in the calendar having seven days, and $\mathcal{K}_G^{\mathbb{T}}$ represents general laws, e.g. that if Monday is a day of a week then it has 24 hours. There is also a finite set $\Delta^{\mathbb{T}}$ of *temporal defeasible rules* representing knowledge that our AmI system agent $\mathcal{A}^{\mathbb{T}}$ is prepared to accept unless it finds counter-evidence. Rules in $\Delta^{\mathbb{T}}$ have the form $\alpha \succ \beta$, where α and β are sets of literals of $\mathcal{L}^{\mathbb{T}}$. $\Delta^{\mathbb{T}}$ will denote the set of basic instances of members of $\Delta^{\mathbb{T}}$. Given space restrictions, our simplified explanation of later sections will actually only use $\Delta^{\mathbb{T}}$ instead of the usually preferable $\Delta^{\mathbb{T}}$ as we merely want to illustrate the potential of argumentation to capture certain key aspects of preference handling.

We will largely adhere to the notation used in [26] and use $(\mathcal{K}^{\mathbb{T}}, \Delta^{\mathbb{T}})$ to denote a *temporal defeasible struc-*

ture, where $\mathcal{K}^{\mathbb{T}}$ is a temporal context and $\Delta^{\mathbb{T}}$ is a finite set of temporal defeasible rules. We will also adopt the same notion of *temporal defeasible consequence*, “ \vdash ”, and the notion of A of $\Delta^{\mathbb{T}}$ as a *temporal argument* for a temporal literal h and the associated notion of a subargument. Let $(\mathcal{K}^{\mathbb{T}}, \Delta^{\mathbb{T}})$ be a temporal defeasible structure of $\mathcal{A}^{\mathbb{T}}$. $\mathbb{T}\mathbf{A}\mathbf{S}\mathbf{T}\mathbf{r}\mathbf{u}\mathbf{c}(\Delta^{\mathbb{T}})$ will be the set of temporal arguments that can be constructed from $(\mathcal{K}^{\mathbb{T}}, \Delta^{\mathbb{T}})$.

Our notion of disagreement is related to time, so given a temporal function $\rho(\{h_1, h_2\})$ which determines whether two temporal literals h_1 and h_2 intersect in their time references, and given two temporal arguments $\langle A_1, h_1 \rangle$ and $\langle A_2, h_2 \rangle$, A_1 for h_1 and A_2 for h_2 are in *disagreement at least about an instant i* , $\langle A_1, h_1 \rangle \bowtie_i \langle A_2, h_2 \rangle$, if and only if $\rho(\{h_1, h_2\}) \neq \emptyset$ and $\mathcal{K}^{\mathbb{T}} \cup \{h_1, h_2\} \vdash \perp$. So at least a common temporal reference is required between the temporal references of the arguments involved in the conflict.

A temporal argument $\langle A_1, h_1 \rangle$ *counterargues* another temporal argument $\langle A_2, h_2 \rangle$ in a basic literal h , if and only if there exists a subargument $\langle A, h \rangle$ of $\langle A_2, h_2 \rangle$ such that $\langle A_1, h_1 \rangle$ and $\langle A, h \rangle$ are in disagreement (in at least an instant i). Let $>$ be a partial order defined over elements of $\mathbb{T}\mathbf{A}\mathbf{S}\mathbf{T}\mathbf{r}\mathbf{u}\mathbf{c}(\Delta^{\mathbb{T}})$, we will say that a temporal argument $\langle A_1, h_1 \rangle$ *defeats* another $\langle A_2, h_2 \rangle$, $\langle A_1, h_1 \rangle \gg_{\text{def}} \langle A_2, h_2 \rangle$, if and only if there exists a subargument $\langle A, h \rangle$ of $\langle A_2, h_2 \rangle$ such as $\langle A_1, h_1 \rangle$ counterargues $\langle A_2, h_2 \rangle$ in h and $\langle A_1, h_1 \rangle > \langle A, h \rangle$.

When there is a conflict between arguments, preference criteria are used to understand whether some arguments may be preferable to others, e.g. specificity. Specificity is based on the structure of the arguments. It has the advantage of being independent from the application domain. Still, there are several other criteria which can be used to compare and select arguments. In some cases *Persistency* over time could be used as a reason to prefer an explanation over another. We assume properties persist unless we have reasons to believe otherwise. We will use predicates $\text{Change}_{at}^{+-}(p, i)$ and $\text{Change}_{in}^{+-}(p, I)$ to indicate that a proposition p changes its truth value from being true to false at an instant i or in an interval I respectively. The following axioms allow the detection of these situations:

$$\begin{aligned} \forall_{\mathcal{P}} p \forall_{\mathcal{T}} i (\text{Holds}_{at}(p, i-1) \wedge \neg \text{Holds}_{at}(p, i) \\ \rightarrow \text{Change}_{at}^{+-}(p, i)) \\ \forall_{\mathcal{P}} p \forall_{\mathcal{I}} I, I' (\text{MEETS}(I, I') \wedge \text{Holds}_{on}(p, I) \wedge \neg \text{Holds}_{on}(p, I') \\ \rightarrow \text{Change}_{in}^{+-}(p, I')) \end{aligned}$$

where “MEETS” should be considered as in [29, 30]. We can also consider analogous axioms for Change_{at}^- and Change_{in}^- for properties changing from being false to being true. Let $\langle A_1, h_1 \rangle, \langle A_2, h_2 \rangle \in \mathbf{TAStruc}(\Delta^T)$, we say that A_1 for h_1 is *preferred under persistency* to A_2 for h_2 , noted $\langle A_1, h_1 \rangle >_{\text{tpers}} \langle A_2, h_2 \rangle$, if and only if $\langle A_2, h_2 \rangle$ use persistency and $\langle A_1, h_1 \rangle$ does not.

In the next sections we assume the following *precedence order* [31] between the preference criteria: $\mathfrak{R} = \{>_{\text{tspec}}, >_{\text{tpers}}, >_{\text{tspec}} > >_{\text{tpers}}\}$. This means we apply specificity first. When the arguments are incomparable under specificity or they are equi-specific we apply the persistency criteria. The next section complements this with a more user personalised preference criterion.

A conclusion C is “justified” when there is at least an argument in support of C and there are no other better counter-argument(s). For a more formal explanation of the notion of “support”, see [26].

3. User Preference Architecture for Argumentation

Figure 1 depicts an overall architecture of how our argumentation system works in handling users preferences. We assume our system gets information from the external world, including information from sensors and information through web services. This information is represented in the knowledge base (top left area of the figure). Depending on the information the system may detect a conflict during decision making and arguments will support the different options (top right area of the figure). Argument comparison strategies will be triggered (right centre of the figure). The heuristics used to compare arguments is decided by the precedence order which defines a hierarchy amongst the different comparison criteria available to the system (left centre of the figure). If this argument comparison process resorts to user preferences then the User Preference Handling Module analyses the arguments detecting parts of the argument which directly relate to user preferences and needs (lower right part of the figure). The comparison of the arguments based on user preferences resorts to the User Preference Order (lower left), which in turn when created or modified is based on the User Preferences Ontology (centre left). The User Preferences Ontology can be provided initially by developers. The user preference order can be changed from time to time by the user. Users preferences can be influenced by the external world.

Imagine the argumentation system wants to compare two arguments A and B (as shown in the upper part of the diagram). The argument comparison module indicates that the arguments A and B are compared with

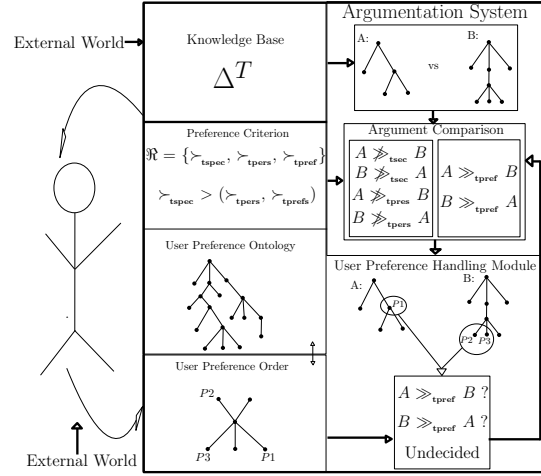


Figure 1: Overall preference Architecture

specificity and persistency established to know which is preferred over the other. The output shows that there is no preferable outcome from the two arguments. When arguments are compared (as shown in the User Preference Handling Module), the options are that either one argument is preferred over the other, or it is undecided. One argument can be preferred over the other due to the relative value in preference. For example, B maybe preferred over A because the relative value combined of $P2$ and $P3$ is greater than that of $P1$. We assume $P1$, $P2$ and $P3$ can be syntactically or semantically linked to the User Preference Ontology module.

The argumentation theory we introduced in the previous section included sorts \mathcal{T} , \mathcal{I} , \mathcal{N} , \mathcal{D} , \mathcal{P} , and \mathcal{A} . We introduce a new sort \mathcal{Pref} which we use to specify *user preferences*. This sort is defined through the User Preferences Ontology. Consequently we extend \mathcal{L}^T to relate those preferences to time. We will use it in a similar way as for other sorts, by means of a predicate $\text{Pref}_{on}(Pr, I)(\text{Pref}_{at}(Pr, i))$ to indicate a preference which applies to a period I (to an instant i).

An agent a can have multiple preferences, represented with a set, $\text{Pref}_a = \{pr_1, pr_2, pr_3, \dots\}$ and we assume they can be represented in a partial order \mathcal{O} . This partial order can produce a structure $\mathcal{O}(\text{Pref}_a)$. For example: $\mathcal{O}(\text{Pref}_a) = (pr_3; pr_1; pr_2)$ meaning pr_3 is preferable to pr_1 and this one to pr_2 , and with $\mathcal{O}(\text{Pref}_a) = ((pr_1, pr_3); pr_2)$ we can represent that pr_1 and pr_3 are equally preferable and these are preferable to pr_2 . This order in practice will typically be partial, as sometimes we have equal preference over two or more aspects of our lives.

Personal preferences also change over time. However

here we do not look in detail at these “belief dynamics”. Instead, we deal with the consequences of those changes as we show in the last example at the end of this paper. That is, we show that in the case of a change of preferences our system can provide different results, but it does not handle changes of preference itself. We assume there is an interface where a change in preferences can be indicated for a specific agent a and it translates this change in a recalculation of $O(Pref_a)$. We assume each agent has at least one preference criterion and the comparison of arguments taking place is for one single agent. For a system considering several users in the same environment, see [21].

We assume a function which measures the relevance of preferences, function f_{Pref} , which can be defined in various domain dependent ways. One possible definition is: $f_{Pref} : D \rightarrow W$, where D is a non-empty set of all possible combinations of $O(Pref_a) \times \langle A, h \rangle$, $O(Pref_a)$ is a partial order as explained further up, $\langle A, h \rangle$ is an argument, and W is a weight (which can be a number or label). This function takes a set of preferences and an argument and measures the level of preference importance in the argument as follows. Let assume an argument $\langle A, h \rangle$ where $A = \{R_1, \dots, R_n\}$ and $R_i = p_1^i \wedge \dots \wedge p_m^i \succ head^i$ where $p_1^i \wedge \dots \wedge p_m^i$ and $head^i$ are predicates, some of them possibly of type $Pref_{on}(Pr, I)$ or $Pref_{at}(Pr, i)$. We define the *preference weight* $w_{(pr_j, a)}$ for pr_j in $O(Pref_a)$ as a number reflecting its level in the partial order. For example we can transform $((pr_1, pr_3); pr_2)$ into $\{(2, pr_1), (2, pr_3), (1, pr_2)\}$ reflecting both pr_1 and pr_3 are equally preferable and rank higher in the preferences than pr_2 . We define the *preference weight of a predicate* p_j , $W_p(p_j)$, where $1 \leq j \leq m$, as the weight given for p_j in $O(Pref_a)$ as above. If $p_j \notin (Pref_a)$ s then $W_p(p_j) = 0$. Then we define the *preference weight of a rule* R_i , $W_r(R_i)$; as the addition of all preference weights of the predicates in its body. Now we can define the *preference weight of an argument* $\langle A, h \rangle$, $W_a(\langle A, h \rangle)$; as the addition of the preference weight of the rules in the argument. That is: $W_a(\langle A, h \rangle) = \sum_{i=1}^n W_r(R_i)$ and $W_r(R_i) = \sum_{j=1}^m W_p(p_j^i)$.

Based on this function which allows us to measure the importance of preferences taking part in an argument we can define another preference criterion:

DEFINITION 1. Let a be an agent, $\langle A_1, h_1 \rangle$ and $\langle A_2, h_2 \rangle \in \mathbb{T}Astruc(\Delta^{\tau_1})$ two arguments and a personal preference measuring function f_{pref} . Then A_1 for h_1 is *user preferable* than A_2 for h_2 in an instant i for agent a , denoted as $\langle A_1, h_1 \rangle \succ_{Upref(a)} \langle A_2, h_2 \rangle$, iff $f_{Pref_a}(A_1) > f_{Pref_a}(A_2)$.

Since we have a new way to compare arguments, we have to redefine the *precedence order* between the

preference criterion: $\mathfrak{R} = \{>_{tspec}, >_{tpers}, >_{Upref(a)}, >_{tspec} > >_{tpers} > >_{Upref(a)}\}$. This means we give priority to domain independent criteria.

As the new precedence order indicates the system considers epistemic conflicts first [18] and if no clear choices arise then it tries to disambiguate the situation looking at conflicts at a more practical level. Unusually for traditional AI approaches, the precedence order allows to change that. We discharge all responsibility of the careful use of that resource to the developers. This can be used as an exception handler in extraordinary circumstances. For example, the Intelligent Environments community operates under strong user-centred principles [32] which secure humans rights over the system and reassures the human to be in control of the system and not the other way around [33]. Similar principles have been considered for robotics. As an simple example, consider you live in a smart home or you are driving a smart car, and this Intelligent Environment is behaving erratically, or at least in a way you consider unacceptable. Then you would like to have the right to shut the system off with an order, the system may argue against it, but cannot prevent it, because humans are in control and the human preference should prevail.

4. Modelling multiple preferences

To illustrate how our system works we assume a smart home with a light management system that is capable of understanding the activities in a room, so as to make reasonable decisions for an inhabitant named Sara. We will be considering a complex description involving three aspect of Sara’s life: lighting, entertainment and health management. We will also be considering a description involving the health management aspect of Joe’s (Sara’s son) life.

4.1. Modelling Sara’s Preferences

Sara is a 65 years old woman living in a smart environment. She would like the system to turn the lights off any time she leaves home and forget to switch off the light. Sara still want the system to be aware of her health circumstances, and provide her with information on food consumption especially her favourite brown-cake which she buys online, despite being diabetic. The system should further manage Sara’s television programmes, making suggestions on potentially interesting programmes.

The above description provides a complex problem to deal with. The light, health and television programme scenario offers three ways of representing users' preferences. The rest of this section will illustrate how argumentation will deal with these scenarios.

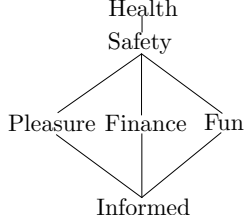


Figure 2: Ranking of Sara's Preferences

According to Figure 2 which depicts Sara's ranking of life style choices, we assume that for her, health is more important than safety, and safety more important than pleasure, finance and fun (all of them with equal level of importance) and those are more important than being informed (news). Then we can represent that in our system, using the motion introduced in Section 3, as follows:

$$Pref_{Sara} = \{ \text{finance, informed, safety, health, fun, pleasure} \}$$

$$O(Pref_{Sara}) = \{ (4, \text{health}), (3, \text{safety}), (2, \text{pleasure}), (2, \text{finance}), (2, \text{fun}), (1, \text{informed}) \}$$

where a pair (N, P) indicates the value of preference weight N for a preference P .

4.1.1. Light Scenario for Sara

Table 1 shows the development of the light scenario through time. The next set of rules are extracted from Δ^T :

$$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2) \wedge MEETS(I_2, I_3)$$

$$Holds_{on}(Movement, I_0) \wedge \neg Holds_{on}(Sleeping, I_0) \wedge \neg Holds_{on}(OnBed, I_0) \wedge Holds_{on}(LightsOn, I_0)$$

- L-R1: $Do_{on}(LeavingHome, I_0) \succ Occurs_{at}(LeftHome, begin(I_1))$
- L-R2: $Occurs_{at}(LeftHome, begin(I_1)) \succ \neg Holds_{on}(Movement, I_1)$
- L-R3: $\neg Holds_{on}(Movement, I_1) \wedge Length(I_1) > 15 \wedge \neg Holds_{on}(OnBed, I_1) \succ \neg Holds_{on}(Home, I_2)$
- L-R4: $\neg Holds_{on}(Home, I_2) \succ Pref_{on}(LightOff, I_2)$
- L-R5: $Pref_{on}(LightOff, I_2) \succ Occurs_{at}(SystemTurnsLightOff, end(I_2))$
- L-R6: $Occurs_{at}(SystemTurnsLightOff, end(I_2)) \succ \neg Holds_{on}(LightsOff, I_3)$

Argument for LightsOn@I₃: As seen from the initial facts, the lights are on, as Sara is in the room. So because of persistency, there is a possibility that the lights will remain on.

$$L.On = \{ Holds_{on}(LightsOn, I_0) \wedge \text{notChange}_{in}^{+-}(LightsOn, [end(I_0), end(I_3)]) \succ Holds_{on}(LightsOn, I_3), Holds_{on}(LightsOn, I_3) \}$$

The argument is reflected in figure 3B.

Argument for \neg LightsOn@I₃: Considering an alternative explanation, given that the system has been programmed to understand when the lights are not needed. The argument indicates that Sara is leaving home at I_0 and is out of home at beginning of I_1 . As a result of this no movements were detected from there onwards. If continued for the next 15 minutes and there is no pressure on the bed at the same time, the system has reasons to believe that Sara is not at home at I_2 . When Sara is not at home over that period, she usually prefers the lights off. So at that moment, the system infers that it is reasonable to turn the lights off. As a result, the lights are off at I_3 .

$$L.Off = \{ Do_{on}(LeavingHome, I_0) \succ Occurs_{on}(LeftHome, I_1), Occurs_{on}(LeftHome, I_1) \succ \neg Holds_{on}(Movement, I_1), \neg Holds_{on}(Movement, I_1) \wedge Length(I_1) > 15 \wedge \neg Holds_{on}(OnBed, I_1) \succ \neg Holds_{on}(Home, I_2), \neg Holds_{on}(Home, I_2) \succ Pref_{on}(LightsOff, I_2), Pref_{on}(LightsOff, I_2) \succ Occurs_{on}(SystemTurnsLightOff, I_2), Occurs_{on}(SystemTurnLightOff, I_2) \succ \neg Holds_{on}(LightsOn, I_3), \neg Holds_{on}(LightsOn, I_3) \}$$

The argument is depicted in figure 3A

From Sara's light scenario, there are two main contending arguments, $L.On \bowtie_{\tau} L.Off$. Neither specificity nor persistency can be applied and we will explain how the system applies users' preferences to decide. Note $L.On$ is based on persistency rule P and $W_r(P) = 0$ because there is no preference predicate contained in P , therefore $W_{Sara}(L.On) = 0$.

Argument $L.Off$ is based on rules L-R1, L-R2, L-R3, L-R4, L-R5, L-R6 and $W_r(L-R1) = 0$, $W_r(L-R2) = 0$, $W_r(L-R3) = 0$, $W_r(L-R4) = 0$, $W_r(L-R6) = 0$.

Now $W_r(L-R5) = V$ where V indicates the value of preference of having the lights off. Lights off is not explicitly mentioned in Sara's preference ranking in Figure 2, we assume that the general preference ontology (as seen in lower left of figure 1) contains the information that

Table 1: Lighting Scenario World Dynamics

$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2) \wedge MEETS(I_2, I_3)$				
$Hold_{s_{on}}(Movement, I_0) \wedge \neg Hold_{s_{on}}(Sleeping, I_0) \wedge \neg Hold_{s_{on}}(OnBed, I_0) \wedge Hold_{s_{on}}(Home, I_0) \wedge Hold_{s_{on}}(LightsOn, I_0)$				
Lighting Scenario	Movement	\neg Movement	\neg Movement	\neg Movement
	\neg Sleeping	\neg Sleeping	\neg Sleeping	\neg Sleeping
	\neg OnBed	\neg OnBed	\neg OnBed	\neg OnBed
	Home	Home	\neg Home	\neg Home
	LightsOn	LightsOn	LightsOn	\neg LightsOn
Transition Cause	$Do_{on}(LeavingHome, I_0)$	System Inference from: L-R3	$Occurs_{at}(\text{System TurnsLightOff, end}(I_2))$	
	I_0	I_1	I_2	I_3

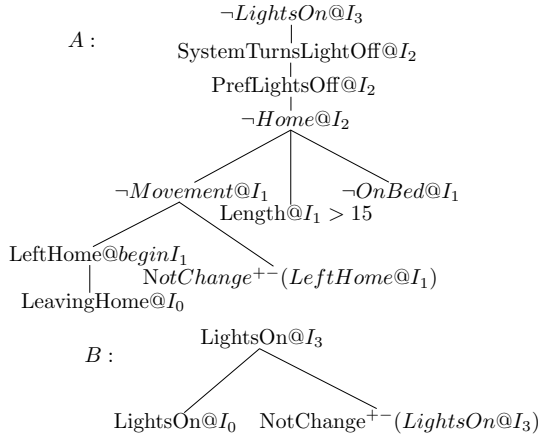


Figure 3: Argumentation Trees for Sara's Light Scenario

connects lights off and $Finance \subset Pref_{Sara}$. According to $O(Pref_{Sara})$, $W_p(Finance) = 2$, so $W_r(L-R5) = 2$. Now we can calculate the weight for the argument which is $W_{Sara}(L.Off) = 0 + 0 + 0 + 0 + 2 + 0 = 2$.

$L.Off \succ_{Upref(Sara)} L.On$ because Sara is not at home and from a financial point of view she prefers the lights off. Therefore, $L.Off \succ_{def} L.On$.

4.1.2. Television Scenario for Sara

Table 2 shows the development of the television scenario through time. The next set of rules are extracted from $\Delta^{\top 1}$:

$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2)$
 $Hold_{s_{on}}(WatchTV, I_0) \wedge \neg Hold_{s_{on}}(WatchingNews, I_0) \wedge \neg Hold_{s_{on}}(WatchingSports, I_0)$

T-R1: $Occurs_{on}(DisastrousEvent, I_0)$
 $\succ Pref_{on}(WatchingNews, I_1)$

T-R2: $Pref_{on}(WatchingNews, I_1) \wedge Hold_{s_{on}}(WatchTV, I_1)$
 $\succ Do_{on}(WatchingNews, I_2)$

T-R3: $Occurs_{on}(FootballMatch, I_0)$

$\succ Pref_{on}(WatchingSports, I_1)$
T-R4: $Pref_{on}(WatchingSports, I_1) \wedge Hold_{s_{on}}(WatchTV, I_1)$
 $\succ Do_{on}(WatchingSports, I_2)$

Argument for Watching News at I_2 : From the initial facts, there are reasons to believe that Sara will watch the news at I_2 . The reason to believe this is because, when a disastrous (important) event occurs, she will prefer to watch news. If Sara watches television at I_1 and a disastrous event happens at I_1 , the system infers that she prefers watching news at I_2 .

$N = \langle \{Occurs_{on}(DisastrousEvent, I_0) \succ Pref_{on}(News, I_1), Pref_{on}(News, I_1) \wedge Hold_{s_{on}}(WatchTV, I_1) \succ Do_{on}(WatchingNews, I_2)\}, Do_{on}(WatchingNews, I_2) \rangle$

Figure 4A represents the above argument.

Argument for Watching Sports at I_2 : An alternative explanation shows why Sara will be watching the Sports. I_0 indicates that there is a football match going on, and the system is aware that Sara is a football fan. So when Sara is watching television at I_1 and prefers to watch sport because there is a football event going on, the system will believe that Sara will prefer watching sports at I_2 .

$S = \langle \{Occurs_{on}(FootballMatch, I_0) \succ Pref_{on}(Sports, I_1), Pref_{on}(Sports, I_1) \wedge Hold_{s_{on}}(WatchTV, I_1) \succ Do_{on}(WatchingSports, I_2)\}, Do_{on}(WatchingSports, I_2) \rangle$

This argument is shown in figure 4B.

From Sara's Television scenario, there are two main contending arguments, $N \bowtie_{\tau} S$. Neither specificity nor persistency can be applied and we will explain how the system applies users' preferences to decide.

N is based on two rules T-R1 and T-R2, $W_r(T-R1) = 0$ because there is no preference predicate contained in the

Table 2: Television Scenario World Dynamics

$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2)$			
$Hold_{on}(WatchTV, I_0) \wedge \neg Hold_{on}(WatchingNews, I_0) \wedge \neg Hold_{on}(WatchingSports, I_0)$			
Television Scenario	WatchTV	WatchTV	WatchTV
	\neg WatchingNews	\neg WatchingNews	\neg WatchingNews
	\neg WatchingSports	WatchingSports	WatchingSports
Transition Cause	$Occurs_{on}(FootballMatch, I_0)$	$Occurs_{on}(DisastrousEvent, I_1)$	
	I_0	I_1	I_2

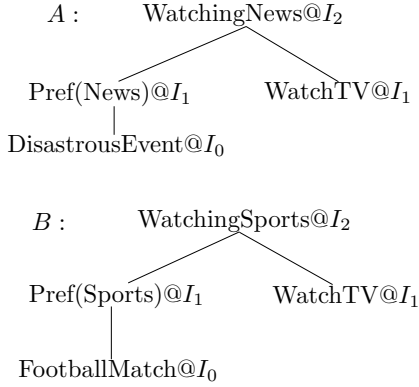


Figure 4: Argumentation Trees for Sara's Television Scenario

antecedent of T-R1. However, $W_r(\text{T-R2}) = V$ where V measures the level of preference for watching news. Watching news or watching sports is not explicitly mentioned in Sara's preference ranking in figure 2, we assume that the general preference ontology (as seen in lower left of figure 1) contains the semantic knowledge that connect watching news to being "Informed" and watching sport to "Fun", both in $Pref_{Sara}$. In this case $W_r(\text{T-R2}) = 1$, therefore $W_{Sara}(N) = 0 + 1 = 1$.

Argument S is based on two rules T-R3 and T-R4, so $W_r(\text{T-R3}) = 0$ because there is no preference predicate contained in the antecedent of T-R3. Although, $W_r(\text{T-R4}) = V$ where V measures the level of preference for watching sports. Watching sport is not explicitly mentioned in Sara's preference ranking in figure 2, we assume that the general preference ontology (as seen in lower left of Figure 1) contain information that connects watching sport to "Fun" indicated in $Pref_{Sara}$. In this case $W_r(\text{T-R4}) = 2$, therefore $W_{Sara}(S) = 0 + 2 = 2$.

From Sara's television scenario, $N \succ_T S$, $S \succ_{\text{Upref}(Sara)} N$ because in Sara's preference ranking, pleasure and fun have priority over being informed. Therefore, $S \succ_{\text{def}} N$.

4.1.3. Health Scenario for Sara (Buying Cake Online)

Table 3 shows the development of the health scenario through time. The next set of rules are extracted from Δ^{T1} :

$$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2) \wedge MEETS(I_2, I_3)$$

$$\neg Hold_{on}(BuyCake, I_0) \wedge Hold_{on}(Diabetic, I_0) \wedge$$

$$\neg Hold_{on}(CakeOnSales, I_0) \wedge \neg Hold_{on}(HighSugar, I_0)$$

H1-R1: $Occurs_{on}(CakeOnSales, I_0)$

$\succ Hold_{on}(CakeOnSales, I_1)$

H1-R2: $Hold_{on}(CakeOnSales, I_1) \wedge Pref_{on}(Pleasure, I_1)$

$\succ Hold_{on}(BuyCake, I_1)$

H1-R3: $Occurs_{on}(HighSugarDetected, end(I_1))$

$\succ Hold_{on}(HighSugar, I_2)$

H1-R4: $Hold_{on}(Diabetic, I_2) \wedge Hold_{on}(HighSugar, I_2) \wedge$

$Hold_{on}(CakeOnSales, I_2) \wedge Pref_{on}(Health, I_2)$

$\succ Occurs_{on}(SystemAdvicesNotBuyCake, I_3)$

H1-R5: $Occurs_{on}(SystemAdvicesNotBuyCake, I_3)$

$\succ \neg Hold_{on}(BuyCake, I_3)$

Argument for Buying Cake at I_3 : As seen from the initial facts, Sara is not buying cake at that moment. The Argument BC expresses the possibility of her buying cake at I_1 , as the argument shows that she prefers to buy cake when on sale.

$BC = \langle \{Occurs_{on}(CakeOnSales, I_0)$

$\succ Hold_{on}(CakeOnSales, I_1),$

$Hold_{on}(CakeOnSales, I_1) \wedge Pref_{on}(Pleasure, I_1)$

$\succ Hold_{on}(BuyCake, I_1)\rangle,$

$Hold_{on}(BuyCake, I_1)\rangle$

Due to persistency the system will advice to buy cake at I_2 and I_3 . This is shown in Figure 5A.

Argument for not Buying Cake at I_3 : Having considered the initial facts that the user is diabetic and this time she has a high sugar level, the system will infer that Sara will not buy cake at I_3 . This is because her ranking in figure 2 indicates that Sara is more concerned about her health compared to her other preferences. This will better inform the system in understanding that Sara's health

Table 3: Health Scenario World Dynamics

$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2) \wedge MEETS(I_2, I_3)$				
$\neg Holds_{on}(BuyCake, I_0) \wedge Holds_{on}(Diabetic, I_0) \wedge \neg Holds_{on}(HighSugar, I_0), \wedge \neg Holds_{on}(CakeOnSales, I_0)$				
Health Scenario	$\neg BuyCake$	$\neg BuyCake$	$\neg BuyCake$	$\neg BuyCake$
	Diabetic	Diabetic	Diabetic	Diabetic
	$\neg HighSugar$	$\neg HighSugar$	HighSugar	HighSugar
	$\neg CakeOnSales$	CakeOnSales	CakeOnSales	CakeOnSales
Transition Cause	$Occurs_{on}(CakeOnSales, I_0)$	$Occurs_{at}(HighSugarDetected, end(I_1))$	$Occurs_{on}(SystemAdvicesNotBuyCake, I_3)$	
	I_0	I_1	I_2	I_3

is a priority and it will give the system reasons to believe that she will not buy cake and will also suggest to the user against buying the cake.

$$\begin{aligned} \neg BC = & \{ \{ Occurs_{on}(HighSugarDetected, end(I_1)) \\ & \succ Holds_{on}(HighSugar, I_2), \\ & Holds_{on}(Diabetic, I_2) \wedge Holds_{on}(HighSugar, I_2) \wedge \\ & Holds_{on}(CakeOnSales, I_2) \wedge Pref_{on}(Health, I_2) \\ & \succ Occurs_{on}(SystemAdvicesNotBuyCake, I_3), \\ & Occurs_{on}(SystemAdvicesNotBuyCake, I_3) \succ \\ & \neg Holds_{on}(BuyCake, I_3) \}, \\ & \neg Holds_{on}(BuyCake, I_3) \} \end{aligned}$$

This argument is depicted in Figure 5B.

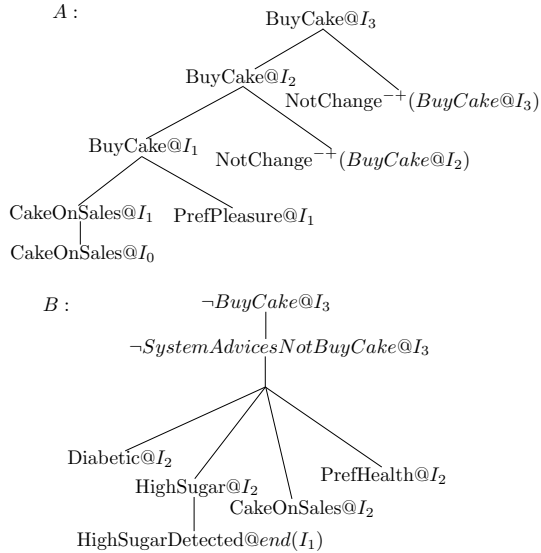


Figure 5: Argumentation Trees for Sara's Health Scenario

From Sara's Health scenario, there are two main contending arguments, $BC \succ_T \neg BC$. Neither specificity nor persistency can be applied and we will explain how the system uses users preferences to decide. BC is based

on two rules H1-R1 and H1-R2, so $W_r(H1-R1) = 0$ because there is no preference predicate contained in the antecedent of H1-R1. However, $W_r(H1-R2) = V$ where V measures the level of preference for pleasure as indicated in $O(Pref_{Sara})$, in this case $W_r(H1-R2) = 2$ and $W_{Sara}(BC) = 0 + 2 = 2$.

$\neg BC$ is based on three rules H1-R3, H1-R4 and H1-R5, with $W_r(H1-R3) = 0$ and $W_r(H1-R5) = 0$ because there is no preference predicate contained in H1-R3 nor in H1-R5. However, $W_r(H1-R4) = V$ where V measures the level of preference for health as indicated in $O(Pref_{Sara})$. In this case $W_r(H1-R4) = 4$, therefore $W_{Sara}(\neg BC) = 0 + 4 + 0 = 4$.

From Sara's health scenario, $BC \succ_T \neg BC$, $\neg BC \succ_{Upref(Sara)} BC$ because in Sara's ranking preference, her health and safety are of higher priority than her other preferences. Therefore, $\neg BC \succ_{def} BC$.

4.2. Modelling Joe's Preferences

Sara has a teenage son, Joe, who cares about pleasure and fun above everything else. He also likes being informed. He prefers being informed over health, safety and finance.

Figure 6 depicts Joe's preference ranking.

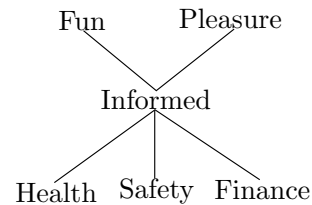


Figure 6: Ranking of Joe's Preferences

Next we represent Joe's preferences using the notation introduced in section 3. Then we can represent this preference ranking in our system as follows:

Table 4: Joe's Health Scenario World Dynamics

$MEETS(I_0, I_1) \wedge MEETS(I_1, I_2)$			
$\neg Holds_{on}(BuyCake, I_0) \wedge \neg Holds_{on}(Diabetic, I_0) \wedge \neg Holds_{on}(HighSugar, I_0) \wedge \neg Holds_{on}(CakeOnSales, I_0)$			
Television Scenario	$\neg BuyCake$	$\neg BuyCake$	$BuyCake$
	$\neg Diabetic$	$\neg Diabetic$	$\neg Diabetic$
	$\neg HighSugar$	$\neg HighSugar$	$\neg HighSugar$
	$\neg CakeOnSales$	$CakeOnSales$	$CakeOnSales$
Transition Cause	$Occurs_{on}(CakeOnSales, I_0)$	System Inference from: H2-R2	
	I_0	I_1	I_2

$Pref_{Joe} = \{ \text{finance, informed, safety, health, fun, pleasure} \}$

$O(Pref_{Joe}) = \{ (3, \text{fun}), (3, \text{pleasure}), (2, \text{informed}), (1, \text{health}), (1, \text{safety}), (1, \text{finance}) \}$

Table 4 shows the development of Joe's health scenario through time. The next set of rules are extracted from $\Delta^{\top 1}$:

$MEETS(I_0, I_1)$
 $\neg Holds_{on}(BuyCake, I_0) \wedge \neg Holds_{on}(Diabetic, I_0) \wedge Holds_{on}(CakeOnSales, I_0) \wedge \neg Holds_{on}(HighSugar, I_0)$

H2-R1: $Holds_{on}(CakeOnSales, I_1) \wedge Pref_{on}(Finance, I_1) \succ \neg Holds_{on}(BuyCake, I_2)$
H2-R2: $Holds_{on}(CakeOnSales, I_1) \wedge Pref_{on}(Pleasure, I_1) \succ Holds_{on}(BuyCake, I_2)$

Arguments for Joe's not BuyingCake at I_2 : From the initial facts and also his preference ranking in figure 6, it shows that Joe cares less about finance compared to pleasure. If the cake is on sale and buying cake requires spending money, and finance is one of the concerns for Joe this could be a reason not to buy the cake at I_1 .

Arguments for Joe's BuyingCake at I_2 : Figure 6 also indicates that Joe has a high preference for pleasure, for example eating chocolate cake is something he enjoys. This provides a reason for Joe to buy the cake.

$\neg BC_j = \langle \{ Holds_{on}(CakeOnSales, I_0) \wedge Pref_{on}(Finance, I_0) \} \succ Holds_{on}(\neg BuyCake, I_1), Holds_{on}(\neg BuyCake, I_1) \rangle$

This argument is shown in Figure 7A.

$BC_j = \langle \{ \neg Holds_{on}(CakeOnSales, I_1) \wedge Pref_{on}(Pleasure, I_1) \} \succ Holds_{on}(BuyCake, I_2), Holds_{on}(BuyCake, I_2) \rangle$

This argument is illustrated in figure 7B.

From Joe's health scenario, there are two main contending arguments, $\neg BC_j \bowtie_{\tau} BC_j$. Neither

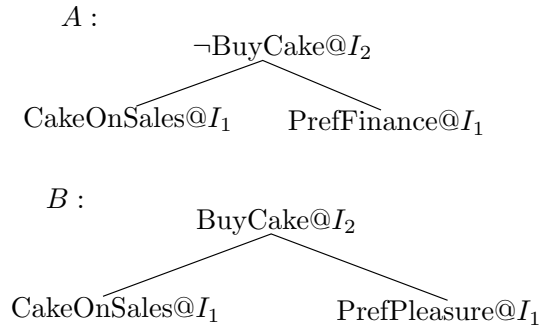


Figure 7: Argumentation Tree for Joe's Health Scenario

specificity nor persistency can be applied and we will explain how the system decides using preferences. $\neg BC_j$ is based on one rule H2-R1, and $W_r(H2 - R1) = 1$ according to the value of *Finance* in $O(Pref_{Joe})$. In this case $W_r(H2 - R1) = 1$, then $W_{Joe}(\neg BC_j) = 1$.

BC_j is also based on one rule $W_r(H2 - R2) = 3$ according to the value of *pleasure* in $O(Pref_{Joe})$. Therefore, in this case $W_{Joe}(\neg BC_j) = 3$.

From Joe's health scenario, $BC_j \bowtie_{\tau} \neg BC_j$, $BC_j \succ_{\text{upref}(Joe)} \neg BC_j$ because *Pleasure* is of higher priority for Joe compared to *Finance*. Therefore, $BC_j \gg_{\text{def}} \neg BC_j$.

5. Conclusions and Further Work

AAL systems are considered as one of the most active research lines inside the Ambient Intelligence community. Its service is essential and expected to improve the satisfaction of users' in the environment. To develop an AAL system for a smart home that will increase users' satisfaction, the system needs to understand and respond to the preferences of users. Through effective management of users' preferences (which should require a rea-

soning tool), the proposed system can automate and provide more viable decisions for the user.

Given that argumentation is a powerful tool for reasoning with inconsistent knowledge [34] and time [26] in this paper we considered how argumentation can be applied to manage users' preferences. Our investigations enable us to conclude that we have found a suitable mechanism to study the computational management of preferences.

We complemented previous argumentation frameworks with a user preference architecture showing how the proposed system handles the reference to users' preferences within arguments. This architecture consists of different modules, a part of the architecture will detect preferences, another will compare preferences and another will link the user specific preferences with more general ontologies. For this to be effective, the system will contain the users' preferences. These preferences will be ranked according to which life style choices the user prefers over others.

The exploration conducted in this paper enables us to validate the effectiveness of argumentation by illustrating its applicability to several practical scenarios. This first approach detects preferences within arguments mostly by syntactical means. Subtler relations between predicates and users preferences can be achieved through a more sophisticated use of ontologies.

Further work focuses on implementation of the system, which will include the creation of a suitable interface that facilitates the flow of preferences from the user to the system, and the integration of the reasoning system into a real smart home.

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