ALI, an Assisted Living System Based on a Human-Centric Argument-Based Decision Making Framework

Esteban Guerrero, Juan Carlos Nieves, and Helena Lindgren

Department of Computing Science
Umeå University
SE-901 87, Umeå, Sweden
(esteban, jcnieves, helena)@cs.umu.se

Abstract. We introduce ALI, a novel approach for Assisted Living systems, which provides assistance and support indoor/outdoor activities of daily life. We integrate a human behavior theory with an argument-based decision making framework. This integration allow us to model a decision making problem from a human activity centric point of view. An activity tracking and monitoring sub-system is proposed in order to: I) send personalized notifications suggesting the most suitable activities to perform (decision making monitoring); II) determine which activities were performed during a period of time (activity recommendation tracking). Our system is exemplified in the paper from the perspective of a person with Mild Cognitive Impairment with particular needs and goals.

Keywords: argumentation, decision making, asssited living systems, activity theory, mobile systems

1 Introduction

The term Mild Cognitive Impairment (MCI) is generally used to refer to a transitional zone between normal cognitive functions and clinically probable Alzheimers disease [1]. A cognitive impairment in individuals with MCI is typically not limited to memory but also other cognitive domains.

In this article we introduce ALI: an Ambient Assisted Living (AAL) system for MCI individuals. ALI represents a novel alternative to address the problem of provide argument-based guidance for individuals with MCI. ALI integrates an Argumentation-based Possibilistic Decision Making Framework (APDMF) [2] and a human behavior framework: Activity Theory [3]. As a result of this integration, ALI deals with uncertain and incomplete information from sensors (mobile devices) and offers both argumentative explanations and interpretations of goal-directed activity (*e.g.* sleep).

By considering an use case of a MCI individual, a running example will be introduced. Let us introduce the following case:

Example 1: **Rut case.** A woman Rut, who is 84 years old, is diagnosed with MCI. She spends almost all her time in an AAL environment, which supports

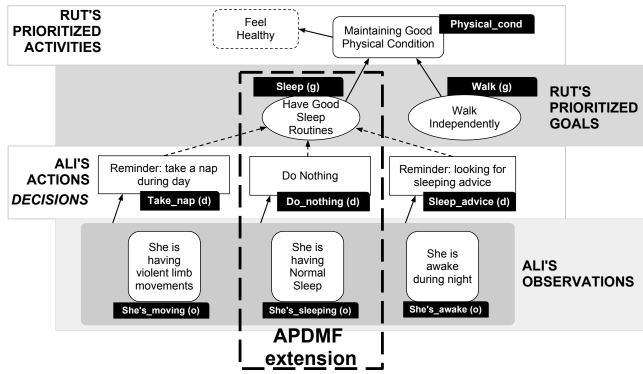

Fig. 1. Rut scenario - Description of Activities from the Agent's Perspective

her daily activities. In this scenario, a therapist evaluates together with Rut her main daily goal-oriented activities, defining a prioritization among them. These *activities* contains *sub-activities* (*e.g.*, *Physical_cond* in the top of Figure 1). Each sub-activity is composed by a sequence of *actions*; these actions are directed by *goals* like *Sleep* and *Walk*, see Figure 1. An intuitive reading of a branch in Figure 1, containing one or more *observations*, a *decision* and a *goal* (dash rectangle), is: given that ALI detects that Rut is sleeping and she wants to sleep, ALI analyses that the best decision is do nothing and let her sleep. Such decisions process is performed by ALI using justified and conflict-free arguments which are selected in a goal-oriented perspective.

Two main tasks are performed by ALI while is running as a mobile application: I) monitoring activities of Rut and guiding her in daily living activities through notifications; and II) tracking her activity for a time lapse, offering to her therapists extra assessment data.

The main contributions of this research are:

- A formal integration between an argument-based possibilistic decision making framework and Activity Theory in order to recognize, argue, justify and provide argumentative explanations for human activities.
- Sets of arguments suggested by argumentation semantics are interpreted based on Activity Theory for selecting and formulating notifying messages.
- A real time activity monitoring-recommender sub-system based on uncertain and incomplete observations of the MCI individual context.
- A modular architecture to recognize and advice about activities to MCI individuals supervised by a health care team.

2 An Argumentation-based Possibilistic Decision Making Framework Integrating Activity Theory

The Rut scenario introduced in Example 1 presents a decision making processes, which have to deal with uncertainty due to data coming from mobile sensors.

We will outline the instantiation of an APDMF framework in the Rut scenario context. The APDMF was formally introduced in [2], is formed by three components: 1) A knowledge base which is defined by a a possibilistic normal logic program P; 2) A set of decisions $\mathcal{D}$ and 3) A set of goals $\mathcal{G}$. Being $\mathcal{D}^*, \mathcal{G}^* \subseteq \mathcal{L}_{P^*}$. In order to illustrate APDMF in the Rut context, let us consider the following example according to Example 1:

Example 2: **Monitoring sleeping patterns of Rut.** Rut agrees with therapists monitor her sleeping patterns using ALI application installed in her mobile phone. When Rut is ready to sleep, she puts her phone under the pillow. In this setting, ALI obtains a log about the movements during her sleep. Each *observation* is represented by a possibilistic rule created by ALI. Let us introduce a subset of possibilistic rules describing this scenario, with *goals, observations* and *decisions* identified with sub-indices *g; o; d* respectively. We can define a possibilistic decision making framework $PDMF_{Rut} = \langle P, \mathcal{G}, \mathcal{D}\rangle$:

$$P{:=}\left\{\begin{array}{cc} 1:\neg Sleep_g \leftarrow She's\_awake_o,\ Do\_Nothing_d & \\ 1: Sleep_g \leftarrow She's\_sleeping_o,\ Do\_Nothing_d & \alpha: She's\_awake_o \leftarrow not\ She's\_sleeping_o \\ 1:\neg Sleep_g \leftarrow She's\_moving_o,\ Do\_Nothing_d & \beta: She's\_sleeping_o \leftarrow not\ She's\_awake_o \\ 1: Sleep_g \leftarrow She's\_awake_o,\ Take\_nap_d & \gamma: She's\_moving_o \leftarrow not\ She's\_sleeping_o \\ 1: Sleep_g \leftarrow She's\_moving_o,\ Sleep\_advice_d & \delta: She's\_sleeping_o \leftarrow not\ She's\_moving_o \end{array}\right\}$$

$$\mathcal{G} := \big\{(\rho, Sleep_g),\ (1-\rho, not\ Sleep_g)\big\}$$

$$\mathcal{D} := \big\{Take\_nap_d, Sleep\_advice_d, Do\_Nothing_d\big\}$$

Since the information obtained from the sensors may contain ambiguity and be inconclusive, each piece of knowledge will be attached with *a degree of confidence* which express the uncertainty degree of each rule (Greek letters whose numerical value belongs to (0,1]). Hence, the knowledge based of ALI basically is a possibilistic logic program [4]. An intuitive reading of a rule in P, $1 : Sleep_g \leftarrow She's\_awake_o,\ Take\_nap_d$ describes a scenario like: given that ALI observes that Rut is awake ($She'\ s\_awake_o$) during the night, a motivational reminder is sent to her mobile: *Message: "If you take a nap now, then you will have good sleep routines" (*$Take\_nap_d$*)*. The set of four rules on the right side in P represents the dependence interaction between observations. The goal $1-\rho$: *not Sleep* defines the possibility for performing the contrary aim for *sleep*.

By considering the framework $PDMF = \langle P, \mathcal{G}, \mathcal{D}\rangle$, and given a function $P\_WFS(S)$ returning a possibilistic well-founded model of a given possibilistic logic program S, we have that an argument A of a decision $d \in \mathcal{D}$ will be composed by three components $\langle S, \mathcal{D}, (g, \alpha)\rangle$ where [2]:

1. $(g, \alpha) \in T$ and $g \in \mathcal{G}$ such that $P\_WFS(S \cup \{1 : d\ \leftarrow \top.\}) = \langle T,\ F\rangle$, being $T,\ F$ sets of possibilistic atoms from which we can infer conclusions.
2. $S \subseteq P$ such that S is a minimal set ($\subseteq$) among the subsets of P *satisfying 1.*

In order to illustrate the process of argument construction, 6 arguments can be obtained from $PDMF_{Rut}$, which are presented in Table 1. Once the arguments are constructed, we must compare the strengths of those arguments, identifying disagreements between arguments (*undercuts* and *rebuts* [5]). Let

A=$\langle S_A,\, d_A,\, g_A\rangle$, $B = \langle\; S_B,\, d_B,\;\; g_B\rangle$ be two arguments, $P\_WFS(S_A \cup \{1\colon d_A \leftarrow \top.\}) = \langle T_A,\, F_A\rangle$ and $P\_WFS(S_B \cup \{1\colon d_B \leftarrow \top.\}) = \langle T_B,\, F_B\rangle$. We say that an argument A attacks B if one of the following conditions holds: 1) *Rebut*: $a \in T_A$ and $\neg a \in T_B$. 2) *Undercut*: $a \in T_A$ and $a \in F_B$. By considering the arguments from Table 1, their attack relationships are presented in the right figure in the same table, in which each argument is represented by a node and each attack relation is represented by an edge.

A_1=$\langle\{1: \neg Sleep\_routine_g \leftarrow She's\_awake_o,\ Do\_Nothing_d$ $\alpha: She's\_awake_o \leftarrow not\ She's\_sleeping_o\}$, $Do\_Nothing_d$, $(\neg Sleep\_routine_g, \alpha)\rangle$	A_5=$\langle\{1: Sleep\_routine_g \leftarrow She's\_awake_o,\ Take\_nap_d$ $\alpha: She's\_awake_o \leftarrow not\ She's\_sleeping_o\}$, $Take\_nap_d$, $(Sleep\_routine_g, \alpha)\rangle$
A_2=$\langle\{1: Sleep\_routine_g \leftarrow She's\_sleeping_o,\ Do\_Nothing_d$ $\beta: She's\_sleeping_o \leftarrow not\ She's\_awake_o\}$, $Do\_Nothing_d$, $(Sleep\_routine_g, \beta)\rangle$	A_6=$\langle\{1: Sleep\_routine_g \leftarrow She's\_moving_o,\ Sleep\_advice_d$ $\gamma: She's\_moving_o \leftarrow not\ She's\_sleeping_o\}$, $Sleep\_advice_d$, $(Sleep\_routine_g, \gamma)\rangle$
A_3=$\langle\{1: Sleep\_routine_g \leftarrow She's\_sleeping_o,\ Do\_Nothing_d$ $\delta: She's\_sleeping_o \leftarrow not\ She's\_moving_o\}$, $Do\_Nothing_d$, $(Sleep\_routine_g, \delta)\rangle$	
A_4=$\langle\{1: \neg Sleep\_routine_g \leftarrow She's\_moving_o,\ Do\_Nothing_d$ $\gamma: She's\_moving_o \leftarrow not\ She's\_sleeping_o\}$, $Do\_Nothing_d$, $(\neg Sleep\_routine_g, \gamma)\rangle$	

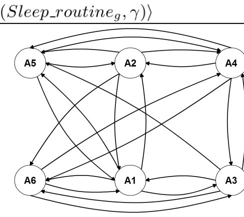

Table 1. Arguments from Rut Scenario

By having a set of arguments (A) and their attack relations ($attacks \subseteq A \times A$), Dung [6] defined the so called *Argumentation Framework (AF)* which is of the form $AF = \langle A,\ attacks\rangle$. Let us assume that given an argumentation framework $AF = \langle A,\ attacks\rangle$, and given a basic argumentation semantics SEM_{Arg} of a possibilistic argumentation decision making framework *PF*, which is a function from PF to $2^{2^{\mathcal{AF}}}$, where $SEM(AF) = \{E_1, \ldots, E_n\}$ such that $E_i \subseteq A$ $(1 \leq i \leq n)$. Usually each E_i is called an *extension* of the argumentation framework AF. In order to compute Dung's argumentation semantics in ALI, we use in ALI architecture the $Wizarg$ library [7] obtaining the follow sets: $SEM_{stable}(PF) = \{\{A_1, A_4\}, \{A_2, A_3\}, \{A_5, A_6\}\}$. In Rut scenario, these two extensions represents sets of justified and conflict-free arguments which will be used in integrating assessment made by a therapist. We are interested in representing extensions and their arguments in terms of goals, which in our scenario are already defined by Rut and her therapists. In consequence, let us consider that given an argumentation framework $APDMF$, a set of argument extensions E induced by an argumentation semantic defined by $E \in SEM(APDMF)$, we have that: $E := \{A_1, A_2, ...A_m\}$ in which each argument $A_i (1 \leq i \leq n)$ is of the form $\langle S_i, d_i, (g_i, \alpha_i)\rangle$. Hence $\varepsilon(E)$ will be defined in terms of its goals sets (g_i, α_i) as follows:

$$\varepsilon(E) := \{(g, \alpha) | (S, d, (g, \alpha) \in E)\} \tag{1}$$

Observe that Equation 1 basically is projecting the goals of each argument. On the other hand, $\varepsilon(E)$ is basically a set of possibilistic atoms. Given a set of possibilistic atoms $\varepsilon(E) := \{(a_1, \alpha_1), \ldots, (a_n, \alpha_n)\}$, $\varepsilon(E)^*$ is $\{a_1, \ldots, a_n\}$. Observe that $\varepsilon(E)^*$ is removing the possibilistic values of $\varepsilon(E)$.

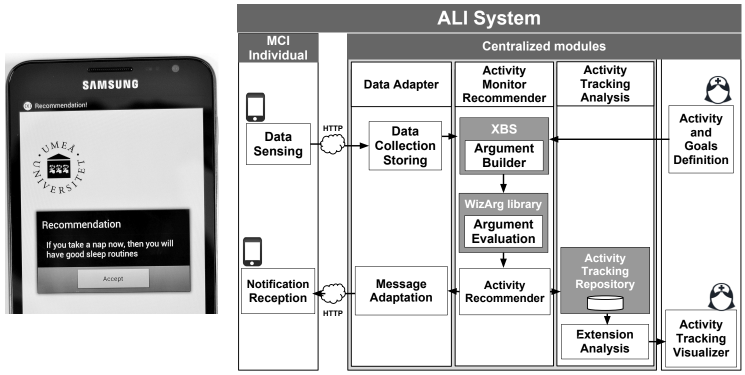

Fig. 2. ALI System. (left: ALI Notification; right: System Architecture)

On the other hand, in order to obtain a human centric interpretation of the found extension sets, we used Activity Theory [8] to represent *activities* in terms of human goals. We define a human *activity* $\mathcal{A}$ as a finite set of *goals* $\mathcal{G}$:

$$\mathcal{A} = \{\mathcal{G}_1, ..., \mathcal{G}_n\} \tag{2}$$

This representation of an activity (2) is consistent with the idea of an extension of an APDMF (1), both of them w.r.t. to goals for be achieved. With this goal-oriented integration we define the concept of *completion* of an activity in order to quantify (*complete, partial, indifferent*) the possibility to perform an activity.

Definition 1. *(Status of activities) Let us consider that given an argumentation framework $APDMF$ in which an extension defined by $E \in SEM(APDMF)$, being SEM an argumentation semantics which induces an extensions set in terms of its goal defined by $E^{\mathcal{G}}$. An activity $Act \in \mathcal{A}$ is:*

- *Complete: iff $Act \subseteq E^{\mathcal{G}}$ for all $E \in SEM(APDMF)$.*
- *Partial: iff $\exists E \in SEM(APDMF)$ such that $Act \subseteq E^{\mathcal{G}}$ and $\exists E^{'} \in SEM(APDMF)$ such that $Act \nsubseteq \exists E^{'\mathcal{G}}$.*
- *Indifferent: iff for all $E \in SEM(APDMF)$, $Act \nsubseteq E^{\mathcal{G}}$*

In order to exemplify Definition 1, let us consider the extensions obtained by arguments in Example 2 and the scenario in Figure 1. In a time lapse when Rut's therapists analyze her activities collected by ALI using her mobile and the recommendations which were offered to her, they can notice that there are goals which were achieved and there are other where ALI does not have information evidence (for instance there are no observations for *Walk* in Figure 1) that were performed. In this case, applying Definition 1, we can say that *Maintaining good physical condition* (Figure 1) is *partially* performed, because the extensions does not have arguments containing observations that Rut is *walking.*

3 Discussion and Conclusions

In this article we present the assisted living system ALI. We exemplified recognition of human activities for guidance and assistance in a defined scenario of a MCI individual. A formal integration between a possibilistic decision making framework and Activity Theory was outlined, in order to recognize, justify and provide argumentative explanations for human activities. The integration allowed us move the focus of analysis to the user goals. An added advantage using the APDMF framework is that ALI can deal with uncertain and incomplete information. We implemented in our system a novel recommendation approach for sending to the MCI individual phone, messages with notifications, trying to motivate the change of some behavior. This novel approach provides to the therapist a useful tool in order to track changes in individuals behavior, being not only applicable for the MCI individuals but also in other contexts. Our approach (Figure 2) fulfills three major requirements: 1) a non-intrusive human recognition alternative; 2) deal with uncertain and incomplete information from sensors, with no data training; and 3) the activity recommendation should be supported and monitored by a health care team.

Different perspectives were used in this interdisciplinary work for the purpose to recognize, infer and recommend human activities. Future work includes improving the Argument Builder module implemented in XSB [9]. ALI system will be integrated dynamically to *ACKTUS*: a system for collaborative argument-based decision-support development in the health domain [10].

References

1. Winblad, B., Palmer, K.: Mild cognitive impairment beyond controversies, towards a consensus: report of the international working group on mild cognitive impairment. Journal of Internal Medicine **256**(3) (2004) 240 – 246
2. Nieves, J.C., Confalonieri, R.: A Possibilistic Argumentation Decision Making Framework with Default Reasoning. In: Fundamenta Informaticae 113. Volume 113. (2011) 41–61
3. Leontiev, A.N.: Lecture 36. Thinking and Activity. Journal of Russian & East European Psychology **43**(5) (2005) 41–52
4. Osorio, M., Nieves, J.C.: Possibilistic Well-Founded Semantics. In Aguirre, A., Borja, R., Garciá, C., eds.: MICAI 2009: Advances in Artificial Intelligence. Volume 5845 of Lecture Notes in Computer Science. Springer Berlin / Heidelberg (2009) 15–26
5. Prakken, H., Vreeswijk, G.: Logics for Defeasible Argumentation. In: Handbook of Philosophical Logic. Kluwer Academic Publishers (2002) 218–319.
6. Dung, P.M.: On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. Artificial Intelligence **77**(2) (September 1995) 321–357
7. Gómez-Sebastià, I., Nieves, J.C.: Wizarg: Visual argumentation framework solving wizard. In: Artificial Intelligence Research and Development conf., Amsterdam, Netherlands, IOS Press (2010) 249–258
8. Kaptelinin, V., Nardi, B.: Activity theory in a nutshell. (2006)
9. Rao, P., Sagonas, K., Swift, T., Warren, D.S., Freire, J.: Xsb: A system for efficiently computing well-founded semantics. In: Logic Programming And Nonmonotonic Reasoning. Springer (1997) 430–440
10. Lindgren, H., Winnberg, P., Winnberg, P.: Domain experts tailoring interaction to users–an evaluation study. INTERACT 2011 (2011) 644–661