

Autonomous adaptation of software agents in the support of human activities

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Abstract. This paper is aimed at formalizing the interplay among a person to be assisted, an assistive agent-based software, and a caregiver. We propose principles that agents should follow in such interplay, this principles may have impact in different agent-based assistive technology. We propose a mechanism to integrate individual's information into the final decision-making process of an agent. Moreover, we endow agents with mechanisms for evaluating the distance between independent and supported activity execution, the so called zone of proximal development (ZPD) in four scenarios: I) independent activity execution by a person; II) ZPD_H activity performance of a person supported by another person (*e.g.* a therapist); III) the ZPD_S representing a potential activities when a person is supported by a software agent; and IV) the ZPD_{H+S} when a person is supported by a caregiver and a software agent. Formal argumentation theory is used as foundation. Our formal models were tested using a prototype using augmented reality as assistive software. A pilot study with older adults and health-care personnel was performed and formal and empirical results are presented.

Keywords: Argumentation theory · Rational agents · Assistive technology · Human activity · Activity theory.

1 Introduction

This paper is aimed at investigating assistive technology using argumentation-based agents and the interplay with individuals that require physical assistance and their caregivers.

We present formal and empirical results on how *intelligent* software adapts to support activities of individuals including, those who need assistance and care givers. The focus of the paper is on the provision of *human-like* characteristics to software agents in order to provide adaptable support, namely *common-sense* and reflection on action decision. The proposed agent model is oriented to reason about human activities, *i.e.*, identify and interpret activities, and support individuals during the execution of physical activities. To this end, representations of complex activities from Activity Theory [15] were utilized to characterize the

knowledge of software agents about human activities and model their decision-making process. Formal argumentation theory is used to provide non-monotonic reasoning to the agents. Moreover, we present a novel information model oriented at how an agent³ may *reflect* on their actions. In human learning literature, reflection enables a person to correct distortions in her/his beliefs and errors in problem-solving [17]. We contribute with a first step on how rational software agents may reflect during the support of human activities.

Finally, as core of our research, we propose a model of adaptation of a support level for agents, based on a computation version of the so-called *zone of proximal development* (ZPD) [23]. Our model of adaptation is formally presented and empirically tested.

The research questions (RQ) addressed in this paper are the following:

- **RQ1:** how an agent may infer potential activities that an individual needs and performs with and without its assistance?
- **RQ2:** in a smart environment scenarios, where individuals require support from others to execute an activity, how an agent-based software may adapt autonomously to team-up with humans to enhance such support?
- **RQ3:** how rational agents can “reflect” on decision to make when a human is in the loop?

This paper is structured as follows: Section 2 presents definitions about how human activities are structured, we also introduce some definitions about formal argumentation theory and argument-based reasoning. In Section 3 our main contributions are presented trying to solve RQ1-3. Using a medical scenario, we developed a prototype to test empirically the level of assistance, some results are presented in Section 4. Conclusions and a discussion is presented in Section 5.

2 Background

In this paper, the human perspective is investigated using Activity Theory [15], which is a social sciences framework oriented to understand human complex activities. On the other hand, formal argumentation theory is used to characterize precisely the internal reasoning of agent software.

2.1 Activity theory

In this paper, activity theory is used with two purposes: 1) for structuring the knowledge of an agent following a hierarchical model; and 2) to understand the potential level of activity achievement of a person.

Activity as structure. An activity consists of a set of *actions*. At the lowest level, an action consists of a set of *operations*. Actions are oriented to goals and are executed by the actor at a conscious level, in contrast with operations which

³ Hereinafter we will identify a rational software agent as just an agent.

do not have a goal of their own and which are executed at the lowest level as automated, unconscious processes. An *activity model* (AT) (see Definition 1) corresponds to information of a person that an agent uses to reason about an activity.

Definition 1 (Activity model). *Let P be a logic program capturing the behavior rules of an activity. \mathcal{L}_P denotes the set of atoms which appear in a program P . An **AT model** is a tuple of the form $\langle Ax, Go, Op \rangle$ in which:*

- $Ax = \{ax_1, \dots, ax_j\} (j > 0)$ is a set of atoms such that $Ax \subseteq \mathcal{L}_P$. Ax denotes the set of actions in an AT model.
- $Go = \{g_1, \dots, g_k\} (k > 0)$ is a set of atoms such that $Go \subseteq \mathcal{L}_P$. Go denotes the set of goals in an AT model.
- $Op = \{o_1, \dots, o_l\} (l > 0)$ is a set of atoms such that $Op \subseteq \mathcal{L}_P$. Op denotes the set of goals in an AT model.

In artificial intelligence literature, this hierarchical structure has been used as framework to represent knowledge of software agents, *e.g.* in [8,10,11,18].

An *activity framework* corresponds to the goals, observations and actions of an agent oriented to assist a human during the execution of an activity, which in turn is represented by the AT model. To capture the knowledge of an agent about its environment, we use *extended logic programs* [7]. An *extended normal program* P is a finite set of extended normal clauses. By \mathcal{L}_P , we denote the set of atoms which appear in a program P . ELP use both strong negation \neg and *not*, representing *common-sense knowledge* through logic programs.

Definition 2 (Activity framework). *An activity framework $ActF$ is a tuple of the form $\langle P, \mathcal{H}_A, \mathcal{G}, \mathcal{O}, AT \rangle$ in which:*

- P is a logic program. \mathcal{L}_P denotes the set of atoms which appear in P .
- $\mathcal{H}_A = \{h_1, \dots, h_i\}$ is a set of atoms such that $\mathcal{H}_A \subseteq \mathcal{L}_P$. \mathcal{H}_A denotes the set of hypothetical actions which an agent can perform in a world.
- $\mathcal{G} = \{g_1, \dots, g_j\}$ is a set of atoms such that $\mathcal{G} \subseteq \mathcal{L}_P$. \mathcal{G} denotes a set of goals of an agent.
- $\mathcal{O} = \{o_1, \dots, o_k\}$ is a set of atoms such that $\mathcal{O} \subseteq \mathcal{L}_P$. \mathcal{O} denotes a set of world observations of an agent.
- AT is an activity model of the form: $\langle Ax, Go, Op \rangle$, following Definition 1.

$ActF$ according to Definition 2 defines the space of knowledge of assistive agents without considering external assistance, for example from other assistive agents (human or software) actions. In this knowledge space, an argument-based process (see Figure 1) can be performed to obtain sets (or sets of sets) of explainable structures *support-conclusion* for what is the best assistive action to take.

Potential level of activity achievement. Vygotsky in [23] proposed to measure the level of development not through the level of current performance, but through the difference (“the distance”) between two performance indicators: 1)

an indicator of independent problem solving, and 2) an indicator of problem solving in a situation in which the individual is provided with support from other people [14]. This indicator was coined as a zone of proximal development ZPD and it has been used extensively in social sciences (see [1,4,13,21]) to understand changes of individuals during assisted learning processes.

ICF qualifiers. The notion of *qualifier* to specify the extent of the functioning or disability of an individual was introduced by the International Classification of Functioning, Disability and Health (ICF)⁴ [19] proposing two main quantifiers: *performance* and *capacity*. In general, a qualifier specifies information about functioning status: the magnitude, the location and the nature of any activity-related problem [20].

2.2 Formal argumentation theory

Argumentation-based systems, have become influential in artificial intelligence particularly in multi-agent systems design (see [3] for a systematic review).

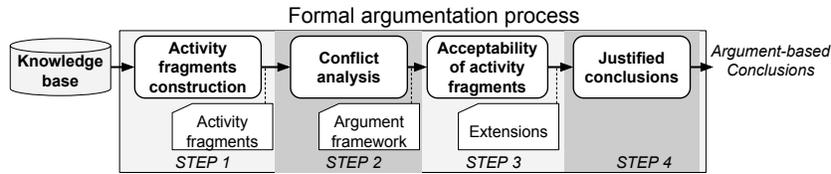


Fig. 1. Inference of an argument-based conclusion using a formal argumentation process

Reasoning about human activities may be performed using a *bottom-up* manner, building *fragments* of an activity explaining the current situation of a person. This process compresses the STEP 1 in Figure 1.

Definition 3 (Hypothetical fragments). Let $ActF = \langle P, \mathcal{H}_A, \mathcal{G}, \mathcal{O}, AT \rangle$ be an activity framework. A hypothetical fragment of an activity is of the form $HF = \langle S, O', h, g \rangle$ such that: 1) $S \subseteq P$, $O' \subseteq \mathcal{O}$, $h \in \mathcal{H}_A$, $g \in \mathcal{G}$; 2) $S \cup O' \cup \{h\}$ is consistent; 3) $g \in T$ such that $ASP(S \cup O' \cup \{h\}) = \langle T, F \rangle$; and 4) S and O' are minimal w.r.t. set inclusion. $ASP(S)$ is a function that returns an answer-set solution of an ELP program, i.e., it provides a common-sense reasoning process given a program as input.

In short, an hypothetical fragment is a consistent manner to explain (inter-connected) parts of an activity. Some of these fragments may be contradictory given inconsistent information in the AT model or/and defeasible information captured by an agent (STEP 2 in Figure 1).

⁴ <http://www.who.int/classifications/icf/en/>

Definition 4 (Contradictory relationships among fragments).

Let $ActF = \langle P, \mathcal{H}_A, \mathcal{G}, \mathcal{O}, Acts \rangle$ be an activity framework. Let $HF_1 = \langle S_1, O'_1, a_1, g_1 \rangle$, $HF_2 = \langle S_2, O'_2, a_2, g_2 \rangle$ be two fragments such that $HF_1, HF_2 \in \mathcal{HF}$. $ASP(Supp(HF_1)) = \langle T_1, F_1 \rangle$ and $ASP(Supp(HF_2)) = \langle T_2, F_2 \rangle$ denote the semantic evaluation of the support, then HF_1 attacks HF_2 if one of the following conditions hold: 1) $\alpha \in T_1$ and $\neg\alpha \in T_2$; 2) $\alpha \in T_1$ and $\alpha \in F_2$.

An argumentation framework is a pair $\langle Args, att \rangle$ in which $Args$ is a finite set of arguments and $att \subseteq Args \times Args$. In [10] an argumentation-based activity framework for reasoning about activities was proposed, by considering argumentation as inference method:

Definition 5 (Activity argumentation framework). Let $ActF$ be an activity framework of the form $\langle P, \mathcal{H}_A, \mathcal{G}, \mathcal{O}, Acts \rangle$; let \mathcal{HF} be the set of fragments w.r.t. $ActF$ and $Att_{\mathcal{HF}}$ or simply Att the set of all the attacks among \mathcal{HF} . An activity argumentation framework AAF with respect to $ActF$ is of the form: $AAF = \langle ActF, \mathcal{HF}, Att \rangle$

Dung in his seminal work [6] introduced a set of *patterns of selection* of arguments called *argumentation semantics*. An argumentation semantics SEM is a formal method to identify conflict outcomes from argumentation frameworks (AF).

Definition 6. Let $AAF = \langle ActF, \mathcal{HF}, Att \rangle$ be an activity argumentation framework AAF with respect to $ActF = \langle P, \mathcal{H}_A, \mathcal{G}, \mathcal{O}, Acts \rangle$. An admissible set of fragments $S \subseteq \mathcal{HF}$ is *stable extension* if and only if S attacks each argument which does not belong to S . *preferred extension* if and only if S is a maximal (w.r.t. inclusion) admissible set of AAF . *complete extension* if and only if each argument, which is acceptable with respect to S , belongs to S . *grounded extension* if and only if it is a minimal (w.r.t. inclusion) complete extension. *ideal extension* if and only if it is contained in every preferred set of AAF .

The sets of arguments suggested by an argumentation semantics are called *extensions*. Let $SEM()$ be a function returning a set of extensions, given an AF such as an AAF. We denote $SEM(AAF) = \{Ext_1, \dots, Ext_k\}$ as the set of k extensions generated by an argumentation semantics w.r.t. an activity argumentation framework AAF .

Definition 7. 1) An fragment $HF_A \in \mathcal{HF}$ is *acceptable* w.r.t. a set S of fragments iff for each fragment $HF_B \in \mathcal{HF}$: if HF_B attacks HF_A , then HF_B is attacked by S . 2) *conflict-free set of fragments* S in an activity is *admissible* iff each fragment in S is acceptable w.r.t. S .

Using these notions of fragment admissibility, different argumentation semantics can draw given an activity argumentation framework (STEP 3 Figure 1):

Definition 8. Let $AAF = \langle ActF, \mathcal{HF}, Att \rangle$ be an activity argumentation framework following Definition 5. An admissible set of fragments $S \subseteq \mathcal{HF}$ is: 1) stable if and only if S attacks each fragment which does not belong to S ; 2) preferred if and only if S is a maximal (w.r.t. inclusion) admissible set of AAF ; 3) complete if and only if each fragment, which is acceptable with respect to S , belongs to S ; and 4) the grounded extension of AAF if and only if S is the minimal (w.r.t. inclusion) complete extension of AAF .

Conclusions of an argument-based reasoning about an activity (see STEP 4 in Figure 1) may be obtained using a *skeptical* perspective, *i.e.*, accepting only irrefutable conclusions as follows:

Definition 9 (Justified conclusions). Let P be an extended logic program, $AF_P = \langle Arg_P, At(Arg_P) \rangle$ be the resulting argumentation framework from P and SEM_{Arg} be an argumentation semantics. If $SEM_{Arg}(AF_P) = \{E_1, \dots, E_n\}$ ($n \geq 1$), then $Concs(E_i) = \{Conc(A) \mid A \in E_i\}$ ($1 \leq i \leq n$). $Output = \bigcap_{i=1 \dots n} Concs(E_i)$.

Where E_i are sets of fragments called extensions. The set of all the extensions generated by $SEM_{Arg}(AF_P)$ are denoted as \mathcal{E}

3 Reflection on decisions about human activity

In this section, we report formal results to understand how autonomous agents may change the level of assistance in different scenarios. Two main formal results are presented in this section: 1) a mechanism for agent’s decision-making based on the individual’s information analyzing consequences of hypothetical actions a mechanism that we called *reflection*; and 2) a formalism to determine the potential of activity performance in four different cases: independence, supported by another person, supported by a software agent and supported by a team person-agent.

3.1 Reflection on decisions about human activity

Conclusions of an argument-based process (Definition 9) about an activity, may contain sets of goal-based conclusions sets, indicating that the agent has different available decision alternatives which are consistent. We propose adding a mechanism for selecting an appropriate decision but considering those agent’s actions that maximize humans’ goals (Go) in an *activity model* (AT model Definition 1). An AT model captures all the information necessary to define a human activity. We condensed this process in Algorithm 1.

In short, Algorithm 1 takes as input the AT model and the set of extensions from a previous common-sense reasoning output. In lines 8-15 of Algorithm 1 a qualifier is calculated (line 12) over sets of sets of fragments (the so-called *extensions* in argumentation theory, see Appendix 2). This qualifier calculation is based on computing a similarity function between the current achievement of human goals in AT (\mathcal{O}_{Go}) *w.r.t.* a set of goal reference (Ref_{Go} line 12). The

Algorithm 1: Goal-based action reflection

```

input      :  $\mathcal{E}, AT$ 
output    :  $h \in \mathcal{H}_A$ 

1  $H \leftarrow \emptyset$  // list of agent's decisions
2  $Go \leftarrow \emptyset$  // list of human's goals
3  $Ref \leftarrow \emptyset$  // list of human's reference goals
4  $numExt = |\mathcal{E}|$  // number of extensions
5  $numArg = |\mathcal{A}|$  // number of arguments per extension
6  $\alpha \leftarrow 0$  // numeric value of a qualifier ( $0 \leq \alpha \leq 4$ )
7  $decisionLat < \alpha, h > =$  // lattice of decisions

8 for  $i \leftarrow 0$  to  $numExt$  do
9   for  $j \leftarrow 0$  to  $numArg$  do
10     $h \leftarrow \text{Act}(hf_j)$ 
11     $\mathcal{O} \leftarrow \text{Obs}(hf_j)$ 
12     $\alpha \leftarrow \mathcal{Q}(\mathcal{O}_{Go}, \text{Ref}_{Go})$  // Qualifier function considering
    observations and a reference value w.r.t. person goals  $Go$ 
13     $decisionLat \leftarrow (\alpha, h)_{hf_j}$  // decision tuple is qualifier and an
    agent's decision w.r.t. the current fragment
14   end
15 end
16 return  $max(\alpha, h)$ 

```

\mathcal{Q} function depicted in line 12, follows the qualifier idea presented in previous approaches [10,11], returning a numerical value ($0 \leq \alpha \leq 4$).

The importance of Algorithm 1 lies on the mechanism for associating a human activity quantification with the internal action decision of an agent. Proposition 1 and Proposition 2 present two special cases of agent's behavior when Algorithm 1 is used⁵. One is the possibility to have a conclusion with no action, and the second expresses an inconclusive behavior given that stable semantics may return \emptyset as output.

Proposition 1. *An agent calculating a goal-based action reflection Algorithm 1 using a skeptical semantics, grounded or ideal, may result in a conclusive empty decision.*⁶

Proposition 2. *An agent calculating a goal-based action reflection Algorithm 1 using the credulous semantics: stable, may result in a inconclusive decision.*⁷

⁵ We refrain of describing fully the proofs of these propositions due the lack of paper space

⁶ Proof sketch: output of grounded and ideal may include $\{\emptyset\}$. See [5]

⁷ Proof sketch: output of stable semantics may include \emptyset . See [5]

3.2 Zone of proximal development using formal argumentation

In this section, based on the common-sense reasoning of activities using argumentation theory, we propose a theory to calculate the following four scenarios in assistive agent-based technology:

I. Independent activity execution This scenario describes an *observer agent* which takes a decision which is purposefully do nothing to support a person, or the decision is empty. More formally, the type of fragments (Definition 3) generated by the agents are with the form $HF = \langle S, O', h^*, g \rangle$ such that $h^* \in \mathcal{H}_A = \{\emptyset, do_Nothing\}$. In this setting, all the extensions generated by $SEM(AF_P) = \mathcal{E}$ during a period of time will create an activity structure. In other words, the cumulative effect of generating fragments, re-construct an activity in a bottom-up manner. Moreover, Algorithm 1 returns only values of α , *i.e.* the current value of a qualifier when the agent does not take any support action. This context defines the baseline of activity execution independence of a person.

II. ZPD_H : activities supported by another person Similarly to previous scenario, the role of the software agent is being an observer. However, built fragments have the form $HF = \langle S, O^*, h^*, g \rangle$ such that $h^* \in \mathcal{H}_A = \{\emptyset, do_Nothing\}$ and $O^* = O' \cup O''$, where O^* is the set of joint observations from the agent's perspective about the individual supported (O') and the supporter O'' . We have that $O' \subseteq O''$, and $O', O'' \neq \emptyset$. In this scenario, O'' is considered a reference set of observations (Ref lines 3 and 12 in Algorithm 1). Algorithm 1 will return a value of α which measures in what extent an individual follows the guide provided by another person.

When multiple extensions are collected during the period of time that the individual is supported, then a different set of activities than individual activity execution may be re-generated in a bottom-up manner.

III. ZPD_S : activities supported by an agent In this scenario, an *assistive agent* takes a decision oriented to uphold human interests. This is a straightforward scenario where $h \in \mathcal{H}_A \neq \{\emptyset, do_Nothing\}$.

IV. ZPD_{H+S} : human-agent supporting In this scenario, the main challenge for the agent perspective is detect: 1) actions that an assistant person executes, and 2) observations of both, the person assisted and the person who attends. This is similar to ZPD_H but with fragments built from $\mathcal{H}_A \neq \{\emptyset, do_Nothing\}$. In this case, the level of ZPD_{H+S} is given by Algorithm 1, and the set of extensions \mathcal{E} with *aligned* goals between agent and human assistant.

Proposition 3. Let \mathcal{O}_{Go} be a set of observations about human goals (*Go*) and actions (*Ax*) framed on an activity, captured by an agent using an activity model *AT*. Let \mathcal{G} and \mathcal{H}_A be agent's goals and its hypothetical actions. In order to provide non-conflicting assistance two properties have to be fulfilled:

- *PROP1*: $\mathcal{O}_{Go} \cap \mathcal{G} \neq \emptyset$
- *PROP2*: $\mathcal{O}_{Ax} \cap \mathcal{H}_A \neq \emptyset$

PROP1 and PROP2 provides coherence among human-agents actions and goals. This two properties may define a first attempt to establish consistency principles of agent-based assistance. This is a future work in our research.

4 Empirical results

In this section, we present results of an empirical evaluation of different values of ZPD. The pilot test was illustrative, aimed at exploring ZPD values in a real setting, then make a qualitatively comparison with our formal approach.

4.1 Prototype and pilot evaluation

The scenario selected to test our approach was framed on supporting an older adult in the activity: *medication management* using a *smart medicines cabinet*. In a smart environment⁸ developed at the *user, interaction and knowledge management* research group⁹, we setup the smart cabinet¹⁰ (see Figure 2).

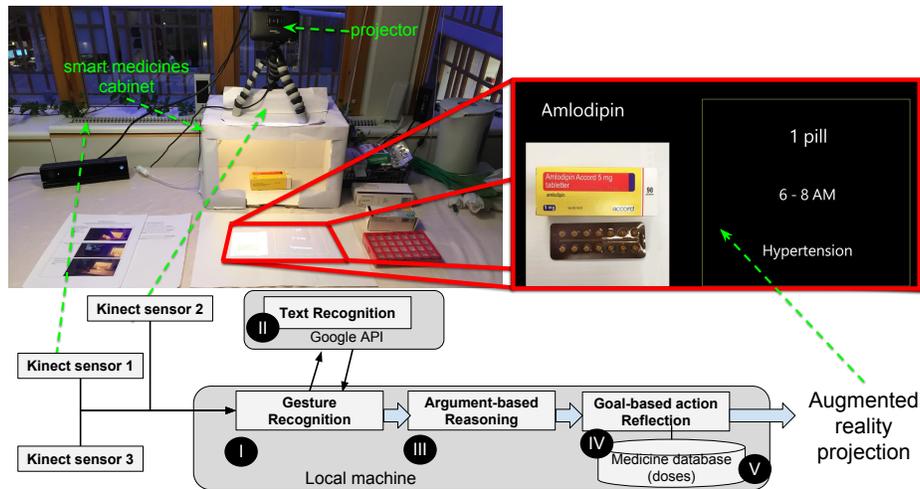


Fig. 2. Smart medicines cabinet using argument-based reasoning and an augmented reality projection. I) Gesture recognition using three Kinect cameras, one for client body capture, another for assistant personal gesture recognition, last one (Kinect sensor 2) on the top of the cabinet to recognize text from medicines boxes; II) Google API for text recognition; III) common-sense reasoning; IV) goal-based action reflection to consider human side; V) database containing doses and timing of pill intake.

⁸ 360 degrees view of the lab: <https://goo.gl/maps/rq3YiF1c5An>

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¹⁰ Due the lack of space, we briefly describe the smart cabinet prototype which is connected to our agent-based platform

Architecture summary: Our prototype consists of five main parts: 1) gestures recognition: obtaining observations from individuals using Kinect cameras; 2) text recognition using another Kinect camera with Google API text recognition (<https://cloud.google.com/vision>); 3) argument-based reasoning: the main agent-based mechanism of common sense reasoning; 4) goal-based action reflection generating an augmented reality feedback: a module to generate support indications as projections in the smart environment; and 5) a database of medicine doses to obtain appropriate messages¹¹. We use three 3D cameras to capture: 1) observations of an individual that needs help in a physical activity; 2) observations of the smart environment, including a supporting person; and 3) information of the handle gestures of medicine manipulation. A central computer was connected to the cameras, processing the information in real-time analyzing gestures of individuals as observations for the agent. The agent platform (JaCaMo) was used to build the agent. An argumentation process was used using an argumentation library previously developed (see [9]). An agent try to update/trigger its plan every frame time that a pre-defined gesture of the 3D camera. Those pre-defined gestures were defined in Stage 1 and Stage 2 with users and experts.

Pilot evaluation setting summary: This pilot study recruited five participants, see Table X. All of the participants had technology experience using computers . The procedure comprised three stages: 1) baseline interview (sub-

Type of user	Age	Sex	Participation		
TA-1	67	M	Stage 1	-	Stage 3
TA-2	71	F	Stage 1	-	Stage 3
TA-3	57	F	Stage 1	-	-
S-1	50	F	-	Stage 2	-
S-2	25	F	-	-	Stage 3

Table 1. Pilot setting

jects: TA-1, TA-2, TA-3 + S-1, S-2); 2) interview with a nurse (S-2); and 3) prototype evaluation (subjects: TA-1, TA-2 + S-2). For a lack of space we only describe the third stage in which participants interact the smart platform. In the third stage, TA-1 participated the evaluation in his home and the other two participates evaluated the system. They were asked to read the instruction message from the augmented reality projection and then, distribute three medications with different prescriptions by using the system. The Assessment of Autonomy in Internet-Mediated Activity protocol (AAIMA) [16] was used to evaluate ZPD. A comparison between our agent ZPD and AAIMA results were obtained. In Table 2 results of ZPD-S and ZPD-H were obtained.

5 Discussion and conclusions

Formal argumentation can be seen as a process consisting of the following

¹¹ Sources and documentation of the prototype can be found in <https://github.com/esteban-g>

Level of activity	Activity description	Level of independence		
Activity	Distribute Medication	TA-1	TA-3	S-2
Level 0	Understands the purpose of the activity but does not participate	A	A	A
Level 1	Contributes with operation information	ZPD-S	ZPD-S	ZPD-S
Level 2	Contributes with medication information	ZPD-S	ZPD-S	ZPD-S
Level 3	Completes the medication distribution	ZPD-H	ZPD-S	ZPD-S
Action	Understand Medication Instruction			
Level 0	Able to trigger the projection of medication instruction	ZPD-S	ZPD-S	ZPD-S
Level 1	Understands the different contents of medication instruction	ZPD-S	ZPD-S	ZPD-S
Level 2	Able to use the instruction to distribute medication	ZPD-S	ZPD-S	ZPD-S
Level 3	Full understanding of the function of the system and its role in medication distribution	ZPD-S	ZPD-S	ZPD-S
Operation	Interact with interaction devices			
Level 0	Basic tasks have a goal in itself, i.e., executed as activities	A	A	A
Level 1	Basic tasks have partly been integrated in activity as actions among other actions	A	A	A
Level 2	Basic tasks are partly operationalized, causes breakdowns but is handled by the individual	ZPD-H	ZPD-H	ZPD-H
Level 3	Basic tasks are operationalised	ZPD-S	ZPD-S	ZPD-S

Table 2. AAIMA Protocol for assessing medication management

Our main contribution in this paper is in general, a formal understanding of the interplay among an assistive agent-based software, a person to be assisted and a caregiver. Moreover, as far as we know, this is a first attempt to formalize the behavior of rational agents using formal argumentation theory, in four scenarios: I) independent activity execution, which resembles the so-called *zone of current development* ZCD [12]; II) ZPD_H which is a set of potential activities that a person can execute with the support of another person (*e.g.* a therapist); III) the ZPD_S representing a potential activities when a person is supported by a software agent; and IV) the ZPD_{H+S} which is the set of activities that a person may be able to perform when is supported by another person and a software agent.

). We propose two properties (Proposition 3) that software agents should follow if their goals are linked to human goals. The relevance and impact of these properties not only covers agents based on formal argumentation theory, but other approaches, such as those based on the Belief Desire Intention model [2].

We propose an algorithm to integrate individual’s information (the AT model Definition 1) into the final decision-making process of an agent. This mechanism captured in Algorithm 1, resembles a process of “reflection” which in humans is a re-consideration of actions and goals given some other parameters. In fact, our reflection mechanism maybe seen as an action-filtering process with the human-in-the-loop¹². We also analyze different outputs of Algorithm 1 considering two groups of argumentation semantics (Propositions 1 and 2).

¹² A concept to integrate human information in *cyber-physical systems* [22]

We evaluate our approach in a three stages pilot study using a scenario of medication management as a complex activity. In this regard, we conducted an experiment with older adults and practitioners to evaluate such activity. We developed a prototype platform using augmented reality projecting assistive messages about medication when a person required some support. For lack of space, we did not fully report in this paper, the full functioning of the platform neither the process of co-design and expert feedback.

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