Reasoning about Human Activities: an Argumentative Approach

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Abstract. Recognizing and supporting human activities is an important challenge for ambient assisted living. In this paper we introduce a novel argumentation-based approach for dealing with human activity recognition. By considering a model of the world and a set of observations of the world, hypothetical fragments of activities are built. The hypothetical fragments of activities will be goal-oriented actions and they will be considered defeasible. Therefore we consider extension-based argumentation semantics for local selection of hypothetical fragments of activities. By considering degrees of fulfillment of activities and local selection, a global selection of hypothetical fragments of the activities is defined. Therefore, we can make explicit statements about why one hypothetical activity was performed.

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1. Introduction

Human activity recognition is a challenging field which goes in a different direction compared to planning methods [10]. For instance, multiple hypotheses are possible regarding the intentions of an observer agent. Knowing a user's activities and goals can significantly improve the effectiveness of the services of an intelligent system. For instance, if a smart home (or a human-aware robot) is providing support to elderly people, it can provide adequate assistive services at the opportune moment, *e.g.*, if a person has mental impairments, the smart home (or the robot) can provide reminders, dynamic tutorials of basic activities such as cooking, *etc*.

Human activity can be understandable in terms of *Activity Theory* (AT). AT is a theoretical framework for studying different forms of human praxis [3]. AT provides a dynamic model of human agent *activity* that integrates both motivational factors (*objectives*) sprung from needs, goal-directed *actions* (cognitive processes) as well as unconscious acts or behavior (*operations*). In AT, an activity is defined by a motive or an objective and is executed by means of a set of *goal-directed actions*.

In a recent work, a systemic-structural analysis of a human activity has been explored [2]. In this analysis, a human activity is carried out through actions, realizing the objective of an activity and generating an outcome. These actions are governed by con-

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scious goals of the subject. A goal reflects the result of an action; hence, the sum of goals reflects the overall objective of an activity. In this setting, an activity can regarded as a set of goals.

Currently there are few *reasoning methods* which could be considered suitable for reasoning about human activities. On the one hand, there are some works in terms on *action specification languages* [1,7,4]. In these works, the *atomic relation* between *conscious goals* and *actions* which is suggested by activity theory is not explicit; therefore, the explanation of both fulfillment and non-fulfilment of activities in terms of goals and actions is not straightforward. On the other hand, in the context of argumentation reasoning, there are less proposals for reasoning about activities [10]. However, we can highlight the work of Konolige and Pollack [9] for plan recognition. In this approach, the authors argue for a *bottom-up approach* based on argumentation and two levels of selection of plan-fragments.

Against this background, we introduce a novel bottom-up approach for activity recognition based on *argumentation reasoning*. More accurately, in order to define the concept of *hypothetic fragments of activities*, we follow the ideas of activity theory which suggests that actions are motivated by needs. The hypothetical fragments of activities will be basically hypothesis about small pieces of activities. In order to select hypothetic fragments of activities which suggest evidence of the fulfillment or non-fulfilment of particular activities, we follow a strategy similar to the one explored by Konolige and Pollack which is based on two selections: *Local selection* and *Global Selection* [9].

1.- Local Selection: The local selection is the first step in the selection of hypothetic fragments of activities. In the local selection, the hypothetic fragments of activities are considered defeasible; therefore, we use *argumentation semantics* [5,6] for selecting a set of sets of hypothetic fragments of activities. This means that basically the local selection leads with the defeasible information which is present in the hypothetic fragments of activities.

2.- Global Selection: By considering the sets of hypothetical fragments of activities suggested by the local section, the global selection defines rules for determining which sets of hypothetical fragments of activities could suggest evidence about the *fulfillment* or *non-fulfilment* of some particular activities. To this end, the global selection defines different degrees of fulfilment and non-fulfilment of activities.

As it was pointed out by Konolige and Pollack, both the local selection and global selection are not easy processes since we will must look for coherent sets of fragments of activities. By coherent, we mean that the union of fragments of activities could suggest the fulfillment of particular activities.

Given that Dung's argumentation semantics are particular relevant in argumentation reasoning, we also explore how the global selection of hypothetical fragments of activities is affected by considering Dung's argumentation semantics at local level selection.

In general terms part of the contributions of this paper are:

- The integration of activity theory and argumentation theory. To the best of our knowledge, this is the first work which tries to achieve this goal.
- An extension of Dung's argumentation approach for capturing activity theory.
- To define a new approach for human activity recognition for smart environments.

- The suggested approach recognizes a human activity and it is also able to argue why a given human activity is achieved or not.
- The behavior of generic argumentation semantics and Dung's argumentation semantics *w.r.t.* activity recognition is studied

The rest of the paper is structured as follows: In Section 2, a basic introduction to Dung's argumentation semantics is presented. In Section 3, the concepts of activity framework and hypothetical fragment of an activity are introduced. In Section 4, the local selection of hypothetical fragments of activities is described. To this end, an attack relation between hypothetical fragments of activities is defined. In Section 5, the global selection of hypothetical fragments of activities is defined. To this end, some rules of fulfilment of activities are introduced. In Section 6, the behavior of the Dung's argumentation semantics *w.r.t.* activity recognition is studied. In the last section, an outline of our conclusions are presented. Due to lack of space, we omit the formal proofs of the theoretical results.

2. Background

In this section, we introduce some basic concepts of argumentation semantics. We start defining some basic concepts of Dung's argumentation approach. The first one is an argumentation framework. An argumentation framework captures the relationships between arguments.

Definition 1 *[5] An argumentation framework is a pair* $AF := \langle AR, attacks \rangle$*, where* AR *is a finite set of arguments, and* attacks *is a binary relation on* AR*,* i.e.attacks $\subseteq AR \times AR$*.*

We say that *a attacks b* (or *b* is attacked by *a*) if $attacks(a,b)$ holds. Similarly, we say that a set *S* of arguments attacks *b* (or *b* is attacked by *S*) if *b* is attacked by an argument in *S*.

Let us observe that an argumentation framework is a simple structure which captures the conflicts of a given set of arguments. In order to select *coherent points of views* from a set of conflicts of arguments, Dung introduced a set of *patterns of selection of arguments*. These patterns of selection of arguments were called *argumentation semantics*. Dung defined his argumentation semantics based on the basic concept of *admissible set*:

Definition 2 *[5]*

- *A set S of arguments is said to be conflict-free if there are no arguments a, b in S such that a attacks b.*
- *An argument* $a \in AR$ *is acceptable with respect to a set S of arguments if and only if for each argument* $b \in AR$*: If b attacks a then b is attacked by S.*
- *A conflict-free set of arguments S is admissible if and only if each argument in S is acceptable w.r.t. S.*

By considering the concept of admissible set, Dung *et al.* introduced five basic argumentation semantics: the grounded, stable, preferred, complete and ideal semantics [5,6]. Even though all of them are based on admissible sets, each of them represents a different pattern of selection of arguments.

Definition 3 *[5,6] Let $AF := \langle AR, attacks \rangle$ be an argumentation framework. An admissible set of argument $S \subseteq AR$ is:*

- *a* stable *extension if and only if S attacks each argument which does not belong to S.*
- *a* preferred *extension if and only if S is a maximal (w.r.t. inclusion) admissible set of AF .*
- *a* complete *extension if and only if each argument, which is acceptable with respect to S, belongs to S.*
- *a* grounded *extension if and only if it is a minimal (w.r.t. inclusion) complete extension.*
- *an* ideal *extension if and only if it is contained in every preferred set of AF.*

$SEM_x(AF)$ denotes the set of extensions of the argumentation framework AF with respect the argumentation semantics x such that $x \in \{s, p, c, g, i\}$ where s stands for stable, p for preferred, c for complete, g for grounded and i for ideal. SEM denotes a generic argumentation semantics such that SEM is a function from AF to $2^{2^{AF}}$.

Given that the set of ideal sets of an argumentation framework defines a total ordered set (*w.r.t.* inclusion), the *maximal ideal set* is usually the interesting ideal set to infer from an argumentation framework. Hence, $SEM_i(AF)$ denotes the maximal ideal set of AF.

3. Activity Argumentation Frameworks

In this section, we will introduce the concept of an *activity framework*. An activity framework will define all the components for building hypothetical fragments of activities. These fragments of activities will define hypotheses about activities.

We assume that the reader is familiar with basic concepts of classical logic. The reader can find a good introduction to classical logic in [11]. In what follows, $\vdash$ denotes classical inference and $\equiv$ denotes logical equivalence.

An activity framework will follow a structure of cognitive state of an agent namely *beliefs*, *desires* and *intentions*:

Definition 4 (An Activity Framework) *An activity framework ActF is a tuple of the form $\langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts \rangle$ in which:*

- *T is a propositional theory. $\mathscr{L}_T$ denotes the set of atoms which appears in T.*
- *$\mathscr{H}_A = \{d_1, \ldots, d_n\}$ is a set of atoms such that $\mathscr{H}_A \subseteq \mathscr{L}_T$. $\mathscr{H}_A$ denotes the set of hypothetical actions which an agent can perform in a world.*
- *$\mathscr{G} = \{g_1, \ldots, g_n\}$ is a set of atoms such that $\mathscr{G} \subseteq \mathscr{L}_T$. $\mathscr{G}$ denotes a set of goals of an agent.*
- *$\mathscr{O} = \{o_1, \ldots, o_n\}$ is a set of atoms such that $\mathscr{O} \subseteq \mathscr{L}_T$. $\mathscr{O}$ denotes a set of observation from a world.*
- *$Acts \subset 2^{\mathscr{G}}$. Acts denotes a set of activities. We are assuming that a set of goals defines an activity.*

Given an activity framework, one can build small pieces of knowledge which give hypothetical evidence of the achievement of a given goal by considering a set of believes (a set of proportional formulas), a *hypothetical action* and a set of observations of the world. These small pieces of knowledge will be called *hypothetical fragments of activities*:

Definition 5 (A Hypothetical Fragment of an Activity) *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts \rangle$ *be an activity framework. A hypothetical fragment of an activity is of the form* $\langle S, O', a, g \rangle$ *such that:*

- $S \subseteq T$, $O' \subseteq \mathscr{O}$, $a \in \mathscr{H}_A$ *and* $g \in \mathscr{G}$
- $S \cup O' \cup \{a\}$ *is consistent.*
- $S \cup O' \cup \{a\} \vdash g$
- S *and* O' *are minimal w.r.t. set inclusion.*

Let us denote by HF_{ActF} *the set of hypothetical fragments which we can construct from* $ActF$.

Let us observe that a hypothetical fragment of an activity is basically *a goal-oriented action* which takes as input observations of the world. From an intuitive point of view, the construction of hypothetical fragments of activities represents the process of building *hypotheses* about the fulfillment of some possible activities. Since the hypothetical fragments of the activities are based on *hypothetical actions*, the hypothetical fragments of activities are *defeasible*. In order to deal with the defeasible information which is present in the hypothetical fragments of activities, we will follow a *defeasible reasoning process* based on *attack relations* between the hypothetical fragments of the activities and argumentation semantics. These two elements will be *the core* for the local selection (the first selection) of the hypothetical fragments of the activities

4. Local Selection of Hypothetical Fragments of Activities

The selection of sets of hypothetical fragments of activities is managed by two steps: *Local Selection* and *Global Selection*. The aim of the local selection is to deal with the defeasible information which is presented in the hypothetical fragments of activities. Hence, we will follow *an argumentation reasoning approach* for selecting sets of hypothetical fragments of activities which could suggest potential fulfillment of activities. In particular, we will use argumentation semantics for selecting sets of hypothetical fragments of activities. To this end, we start defining an attack relation between hypothetical fragments of activities.

Definition 6 (Attack relation) *Let* $ActF$ *be an activity framework and* $F_1, F_2 \in HF_{ActF}$ *such that* $F_1 = \langle S_1, O'_1, a_1, g_1 \rangle$, $F_2 = \langle S_2, O'_2, a_2, g_2 \rangle$. F_1 *attacks* F_2 *if one of the following conditions hold:*

- $\exists x \in S_2$ *such that* $x \equiv \neg g_1$.
- $g_2 \equiv \neg g_1$

$Att_{HF_{ActF}}$ *denotes the set of attacks which occurs between hypothetical fragments of activities which belong to* HF_{ActF}.

By regarding hypothetical fragments of activities as *arguments*, Definition 6 basically is defining an attack relation between arguments. Therefore, we can use argumentation semantics for selecting sets of hypothetical fragments of activities. To this end, let us define the concept of argumentation activity framework as follows:

Definition 7 *Let $ActF$ be an activity framework. An activity argumentation framework AAF with respect to $ActF$ is of the form: $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}} \rangle$.*

By *abusing of notation*, an argumentation semantics SEM, as was defined in Section 2, will infers a set of sets of hypothetical fragments of activities from an activity argumentation framework. In this setting, activity argumentation frameworks are regarded as argumentation frameworks and hypothetical fragments of activities as atomic arguments. Therefore, an argumentation semantics SEM will define the local selection (*initial selection*) of hypothetical fragments of activities.

5. Global Selection of Hypothetical Fragments of an Activity

Selecting hypothetical fragments of activities by considering argumentation semantics is only one of the steps of activity recognition. An argumentation semantics can only suggest *multiple competing* sets of hypothetical fragments of activities which could suggest the fulfillment of some activities. Therefore, we require *a global selection* of hypothetical fragments of activities. By global selection, we mean a selection able to:

- suggest degrees of both fulfillment and non-fulfillment of activities; moreover,
- suggest evidence for believing about the fulfillment of activities.

Given that a hypothetical fragment of an activity always has a goal, a set of hypothetical fragments of activities can be regarded as a set of goals. To this end, let us define the following notation: Given a set of hypothetical fragments of activities E, $E^{\mathscr{G}}$ is defined as follows: $E^{\mathscr{G}} = \{g | \langle S, O', a, g \rangle \in E\}$.

By considering that a set of hypothetical fragments of activities can be regarded as a set of goals, the status of an activity is defined as follows:

Definition 8 (Status of Activities) *Let $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts \rangle$ be an activity framework, $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}} \rangle$ be an activity argumentation framework with respect to $ActF$ and SEM be an argumentation semantics. An activity $Act \in Acts$ is:*

- achieved *iff $Act \subseteq E^{\mathscr{G}}$ for all $E \in SEM(AAF)$.*
- partially-achieved *iff $\exists E \in SEM(AAF)$ such that $Act \subseteq E^{\mathscr{G}}$ and $\exists E' \in SEM(AAF)$ such that $act \nsubseteq E'^{\mathscr{G}}$*
- null-achieved *iff for all $E \in SEM(AAF)$, $Act \nsubseteq E^{\mathscr{G}}$*

It is important to observe that an extension $E \in SEM(AAF)$ is suggesting fragments of activities which argue why a particular activity is fulfilled.

One can observe that there are preservations of status between activities. For instance, one can show that any sub-activity from an achieved activity is achieved, the intersection of two achieved activities is achieved and the union of two achieved activities is achieved.

Proposition 1 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$ *and* SEM *be an argumentation semantics.*

a) *If* $Act_1, Act_2 \in Acts$ *such* $Act_2 \subseteq Act_1$ *and* Act_1 *is achieved w.r.t.* $SEM(AAF)$ *then* Act_2 *is achieved w.r.t.* $SEM(AAF)$*.*

b) *If* $Act_1, Act_2, Act_3 \in Acts$ *such* $Act_1 \cap Act_2 = Act_3$*, and* Act_1*,* Act_2 *are achieved w.r.t.* $SEM(AAF)$ *then* Act_3 *is achieved w.r.t.* $SEM(AAF)$*.*

b) *If* $Act_1, Act_2, Act_3 \in Acts$ *such* $Act_1 \cup Act_2 = Act_3$*, and* Act_1*,* Act_2 *are achieved w.r.t.* $SEM(AAF)$ *then* Act_3 *is achieved w.r.t.* $SEM(AAF)$*.*

Similar to the case of achieved activities, one can see that any activity which contains null-achieved sub-activities are null-achieved.

Proposition 2 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$ *and* SEM *be an argumentation semantics.*

a) *If* $Act_1, Act_2 \in Acts$ *such* $Act_2 \subseteq Act_1$ *and* Act_2 *is null-achieved w.r.t.* $SEM(AAF)$ *then* Act_1 *is null-achieved w.r.t.* $SEM(AAF)$*.*

b) *If* $Act_1, Act_2, Act_3 \in Acts$ *such* $Act_1 \cup Act_2 = Act_3$ *and* Act_1*,* Act_2 *are null-achieved w.r.t.* $SEM(AAF)$ *then* Act_3 *is null-achieved w.r.t.* $SEM(AAF)$*.*

By considering the number of goals of each activity, one can define different degrees of achievement *w.r.t.* each activity. Indeed, one can define a degree of achievement and a degree of non-achievement.

Definition 9 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$*,* SEM *be an argumentation semantics and* $Act_1 \in Acts$ *such that* $Act_2 \subseteq Act_1$*.*

- Act_1 *is* (i/n)*-achieved if* Act_2 *is achieved w.r.t.* $SEM(AAF)$*,* $i = |Act_2|$ *and* $n = |Act_1|$*.*
- Act_1 *is* $(1 - i/n)$*-null-achieved if* Act_2 *is achieved w.r.t.* $SEM(AAF)$*,* $i = |Act_2|$ *and* $n = |Act_1|$*.*
- Act_1 *is* (i/n)*-hard-null-achieved if for all* $E \in SEM(AAF)$*,* $Act_2 \cap E^{\mathscr{G}} = \emptyset$*,* $i = |Act_2|$ *and* $n = |Act_1|$*.*

From the degrees of achieving introduced by Definition 9, one can identify relationships between them.

Proposition 3 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$ *and* SEM *be an argumentation semantics.*

a) *If* $Act \in Acts$ *is achieved, then* Act *is (1)-achieved otherwise* Act *is* (i)*-acceptable such that* $i < 1$*.*

b) *If* $Act \in Acts$ *is partially-achieved, then* Act *is* (i)*-achieved such that* $i < 1$*.*

c) *If* $Act \in Acts$ *is null-achieved, then* Act *is (1)-null-achieved.*

Proposition 4 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$ *and* SEM *be an argumentation semantics.*

a) *If* $Act \in Acts$ *is 0-achieved, then* Act *is null-achieved.*
b) *If* $Act \in Acts$ *is 0-null-achieved, then* Act *is achieved.*

By considering *the number of extensions* that make a given activity partially-achieved, one can define a preference relations between partially-achieved activities.

Definition 10 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$*,* SEM *be an argumentation semantics,* $Act_1, Act_2 \in Acts$ *such that* Act_1*,* Act_2 *are partially-achieved activities. The preference relation* $\succeq_n$ *between partially-achieved activities is defined as follows:*

$Act_2 \succeq_n Act_1$ *if and only if* $|\mathscr{E}(Act_2, SEM(AFF))| \geq |\mathscr{E}(Act_1, SEM(AFF))|$

where $\mathscr{E}(Act, SEM(AFF)) = \{E | E \in SEM(AFF)$ *and* $Act \subseteq E\}$.

6. The status of an activity by considering Dung's semantics

In the previous section, we have explored the status of activities *w.r.t.* no-particular argumentation semantics. In this section, we will identify some basic relations *w.r.t.* the status of an activity by considering different argumentation semantics based on admissible sets.

As we saw in Section 2, Dung *et al.* introduced five argumentation semantics. All of them are based on the concept of *an admissible set*. These semantics can be split into two groups: skeptical semantics and credulous semantics. On one hand, the grounded and ideal semantics are considered skeptical semantics. On the other hand, the stable, preferred and complete semantics are considered credulous semantics.

Given that the skeptical semantics only identify a unique extension from a given argumentation framework, the grounded and ideal semantics do not identify partially-achieved activities.

Proposition 5 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$*,* SEM *be an argumentation semantics and* $\mathscr{N}_{SEM}(AAF) = \{A | A \in Acts$ *and* A *is partially-achieved w.r.t.* $SEM(AAF)\}$.

a) $\mathscr{N}_{SEM_g}(AAF) = \emptyset$
b) $\mathscr{N}_{SEM_i}(AAF) = \emptyset$

It is known that the maximal ideal set is a superset of the grounded semantics [6]. Hence, the status of an achieved activity or a null-achieved activity *w.r.t.* the grounded semantics is preserved *w.r.t.* the ideal semantics.

Proposition 6 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts\rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}}\rangle$ *be an activity argumentation framework with respect to* $ActF$ *and* $A \in Acts$.

a) *If A is achieved w.r.t.* $SEM_g(AAF)$ *then A is achieved w.r.t.* $SEM_i(AFF)$.
b) *If A is null-achieved w.r.t.* $SEM_g(AAF)$ *then A is null-achieved w.r.t.* $SEM_i(AFF)$.

By the definition of the ideal semantics, it is known that an ideal extension is contained in every preferred extension. Hence, one can identify the following property *w.r.t.* achieved activities and ideal semantics.

Proposition 7 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts \rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}} \rangle$ *be an activity argumentation framework with respect to ActF and* $A \in Acts$. *If A is achieved w.r.t.* $SEM_i(AAF)$ *then A is achieved w.r.t.* $SEM_p(AAF)$.

Dung showed that every stable extension is a preferred extension but not vice versa [5]. This property suggests the following properties between activities and these argumentation semantics:

Proposition 8 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts \rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}} \rangle$ *be an activity argumentation framework with respect to ActF and* $A \in Acts$.

a) *If A is achieved w.r.t.* $SEM_p(AAF)$ *and* $SEM_s(AAF) \neq \emptyset$ *then A is achieved w.r.t.* $SEM_s(AAF)$.
b) *If A is partially-achieved w.r.t.* $SEM_s(AAF)$ *then A is partially-achieved w.r.t.* $SEM_p(AAF)$.
c) *If A is null-achieved w.r.t.* $SEM_p(AAF)$ *and* $SEM_s(AAF) \neq \emptyset$ *then A is null-achieved w.r.t.* $SEM_s(AAF)$.

Given that the grounded semantics is exactly the intersection of the complete extensions and the grounded extension is a subset of the intersection of the preferred extensions, one can identify the following properties.

Proposition 9 *Let* $ActF = \langle T, \mathscr{H}_A, \mathscr{G}, \mathscr{O}, Acts \rangle$ *be an activity framework,* $AAF = \langle ActF, HF_{ActF}, Att_{HF_{ActF}} \rangle$ *be an activity argumentation framework with respect to ActF and* $A \in Acts$.

a) *If A is achieved w.r.t.* $SEM_g(AAF)$ *iff A is achieved w.r.t.* $SEM_c(AFF)$.
b) *If A is achieved w.r.t.* $SEM_g(AAF)$ *then A is achieved w.r.t.* $SEM_p(AFF)$.
c) *If A is achieved w.r.t.* $SEM_c(AAF)$ *then A is achieved w.r.t.* $SEM_p(AFF)$.

7. Conclusions

In this paper we have presented a novel bottom-up approach to human activity recognition. This approach takes as starting point *activity theory* which argues for goal-oriented actions which are motivated by needs. In our approach the general problem of activity recognition is captured by the so called *activity frameworks* which have as input a predefined set of activities in terms of sets of goals.

In order to recognize activities, we build *hypothetic fragments of activities* from a given activity framework. We defined a calculus of attacks between hypothetic fragments of activities in order to deal with the defeasible information which is present in the hypothetic fragments of activities. Therefore, the selection of hypothetic fragments of activities is based on two selections: a local selection and a global selection. Both the local selection and global selection are not easy processes since we will must look for coherent sets of fragments of activities.

We have shown that by considering argumentation semantics for the local selection, we can define different degrees of fulfilment and non-fulfilment of activities at global selection level. Let us observe that these degrees of fulfilment and non-fulfilment define a kind of error-measurement. It is worth mentioning that authors such as Kautz [8] has pointed out the relevance of defining error-measurements in *plan recognition*. Hence, it is quite obvious that considering error-measurements is also relevant in activity recognition. We have identified different relations *w.r.t.* the status of an activity by considering different argumentation semantics. These relations define different strategies for implementing our approach.

As part of our future work, we consider an implementation of our approach in order to validate the suggested approach with real scenarios. Due to lack of space, we have not presented examples.

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References

[1] C. Baral and M. Gelfond. Reasoning about Intended Actions. In *AAAI*, pages 689–694. AAAI Press / The MIT Press, 2005.

[2] G. Bedny and W. Karwowski. Introduction to applied and systemic-structural activity theory. In *Human-Computer Interaction and Operators Performance: Optimizing Work Design with Activity Theory*, page 464. CRC Press Taylor & Francis Group, Boca Raton, Florida, 2011.

[3] O. W. Bertelsen and S. Bø dker. Activity Theory. In J. M. Carrol, editor, *HCI Models, Theories, and Frameworks: Toward an Interdisciplinary Science*, chapter 11, pages 291–324. Morgan Kaufmann, 2003.

[4] J. Blount and M. Gelfond. Reasoning about the intentions of agents. In *Logic Programs, Norms and Action*, volume 7360 of *Lecture Notes in Computer Science*, pages 147–171. Springer, 2012.

[5] P. M. Dung. On the acceptability of arguments and its fundamental role in nonmonotonic reasoning, logic programming and n-person games. *Artificial Intelligence*, 77(2):321–358, 1995.

[6] P. M. Dung, P. Mancarella, and F. Toni. Computing ideal sceptical argumentation. *Artificial Intelligence*, 171(10-15):642–674, 2007.

[7] A. Gabaldon. Activity recognition with intended actions. In *IJCAI*, pages 1696–1701, 2009.

[8] H. Kautz. *Reasoning About Plans*, chapter .A Formal Theory of Plan Recognition and its Implementation, pages 69–126. Morgan Kaufmann Publishers, 1991.

[9] K. Konolige and M. E. Pollack. Ascribing plans to agents. In *Proceedings of the 11th International Joint Conference on Artificial Intelligence (IJCAI). Detroit, MI, USA*, pages 924–930. Morgan Kaufmann, 1989.

[10] F. Sadri. *Ambient Intelligence and Smart Environments: Threds and Perspectives*, chapter Logic-Based Approaches to Intention Recognition, pages 346–375. IGI Gobal, 2011.

[11] D. van Dalen. *Logic and structure*. Springer-Verlag, Berlin, 3rd., aumented edition edition, 1994.