Using Formal Argumentation for Handling Temporality in Human Activity Reasoning

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Abstract

Human-aware Artificial Intelligent systems are goal directed autonomous systems that are capable of interacting, collaborating, and teaming with humans. In this sense, human activity reasoning plays a significant role in human-computer interaction. In this context, it is important to consider the temporality of such evidence in order to distinguish activities and to analyse the relations between them. This work tackles the problem of reasoning about activities a human performs considering their temporality and durability and possible overlappings between them. Thus, the main contribution is an argumentation-based framework for reasoning about human activities.

1 Overview and Contributions

In the last years, a part of Artificial Intelligence (AI) researchers have focused their efforts in human-centric applications such as intelligent tutoring systems or social robotics. Thus, as human-AI interaction increases, there is a need for developing human-aware AI systems. The idea behind these systems is to develop approximate models about the human in order to better interact with him/her. In (Kambhampati 2020), some challenges about human-aware AI systems are discussed. Such challenges include recognizing humans intentions (or goals) and capabilities in order to provide an appropriate help to them or generating explanations.

This work tackles the problem of reasoning about activities a human performs. This reasoning is carried out in two phases, the first one is called *local selection*, which is based on Timed Argumentation Frameworks (TAFs) (Budán et al. 2012) and aims to construct a temporal model of the possible performed activities and determine different activities or activities that can be performed together without problem. The second phase is called *global selection* and aims to determine the degree of fulfilment of possible activities recognised in phase one.

Figure 1 shows the different activities a man, called `Bob`, performs from 17h until 6h. The activities are monitored and can be perceived in form of hypothetical fragments of activities [1] (`F1` to `F11` in Figure 1), which can be seen as hypothesizes with respect to what it is been observed. The system compares these fragments for "reasoning" about the human behavior in terms of activities and distinguish them. Such fragments are constructed from observations, actions, and goals. Figure 2(a) shows fragments `F9`, `F10`, and `F11`, observations $\mathcal{O}'$, actions a, and goals g. We have that fragment `F9` states that `Bob` is in the bedroom (o_4) putting on his pyjama (a_{12}) with the goal of trying to sleep (g_{12}). The idea is that conflicting fragments may determine different activities or compatible activities. With conflict, we mean inconsistent observations, actions, or goals and with compatible, we mean activities that can be performed at the same time even when there is a conflict between them (e.g., *watching tv* and *eating*). Figure 2(b) shows that `F11` has a conflict with `F9` and `F10` because they have inconsistent goals (denoted by $reason$); however, only there is an attack (`att`) between `F10` and `F11`.

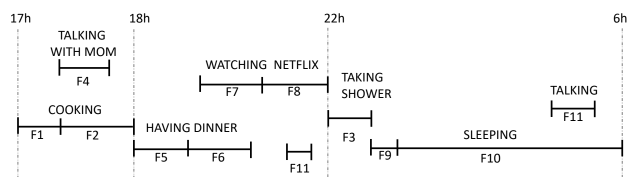

Figure 1: `Bob`'s activities after work from 17h until 6h and recognized hypothetical fragments.

ID	$\mathcal{O}'$	a	g
F_9	$\{o_4\}$	a_{12}	g_{12}
F_{10}	$\{o_4\}$	a_4	g_3
F_{11}	$\{o_3\}$	a_1	g_2

(a)

conf	$reason$	TEMPREL	att
(F_9, F_{11})	$g_{12} \equiv \neg g_2$	b	-
(F_{10}, F_{11})	$g_3 \equiv \neg g_2$	d^-	+

(b)

Figure 2: Fragments, conflicts, and attack examples.

Since we have to deal with inconsistency, we can use formal argumentation; hence, we apply argumentation semantics for obtaining consistent (or acceptable) sets of fragments. We specifically base on TAFs, which are an extension of Abstract AFs (AAFs) (Dung 1995) that are composed of a set of abstract arguments and a binary relation encoding attacks between such arguments. In TAFs, arguments are valid only during specific time intervals. This impacts on the attack relation, which is only considered when both the attacker and the attacked arguments are available in the same time interval. In activity reasoning, we can see fragments as arguments and conflicts between them as possible attacks. Conflicts do not always represent attacks due to

[1]Hereafter referred just as fragments.

the temporality component. For example, assume that there is a set of fragments for *cooking* (F1 and F2) and another for *taking a shower* (F3). Although both activities are conflicting – because a person cannot be frying something and taking a shower at the same time – both of them were performed by Bob. Since they were performed in different time intervals, no attack arises. Let now assume that the fragment of *talking* (F3) is detected in the same time interval of the fragment of *sleeping* (F11). This conflict may indeed lead to emerging attack because it is not normal to consciously talk while one is sleeping. Thus, it is important to analyse attacks between fragments taking into account the temporal relations between them.

We use (Allen 1983)'s interval algebra to represent the durability and the temporal relation between fragments (see Figure 3 for some examples of temporal relations) and TAFs for the reasoning. With respect to TAFs, we had to extend the attack notion in TAF for supporting activity reasoning. In TAF, when there is an attack relation between two arguments, this holds for all the intervals where both of them belong; however, in activity reasoning the attack relation between two conflicting fragment (arguments) depends on their temporal relation. Thus, when they have a sequential relation (e.g., before) there is not an attack; otherwise (e.g., overlaps), it exists. In Figure 2(b), we can see that there is a conflict between F9 and F11; however, they do not attack because their temporal relation is *before*. On the other hand, there is a conflict and attack between F10 and F11 because their temporal relation is *contains*. Thus, we define two types of attacks. When two fragments attack each other in all the intervals they belong we say that there is a *strong attack* relation between them; otherwise, there is a *weak attack* relation. We also had to extend other TAF concepts such as defense and acceptability, which are related to the type of attack.

Relation	Notation	Diagram
se_i (before) se_j	$se_i (b) se_j$	
se_i (overlaps) se_j	se_i (o) se_j	
se_i (during) se_j	se_i (d) se_j	
se_j (contains) se_i	se_j (d^-) se_i	

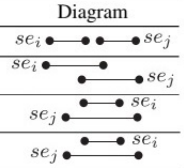

Figure 3: Temporal relations. *se* means sub-event of an activity.

In our example, we work with three intervals: [17, 18], [18, 22], and [22, 6]. After applying the preferred semantics we obtain two extensions: $\mathcal{E}_1 = \{(F_2, \{[17,18]\}), (F_4, \{[17,18]\}), (F_5, \{[18,22]\}), (F_6, \{[18,22]\}), (F_7, \{[18,22]\}), (F_8, \{[18,22]\}), (F_{11}, \{[18,22]\}), (F_3, \{[22,6]\}), (F_9, \{[22,6]\}), (F_{10}, \{[22,6]\})\}$ and $\mathcal{E}_2 = \{(F_4, \{[17,18]\}), (F_5, \{[18,22]\}), (F_6, \{[18,22]\}), (F_7, \{[18,22]\}), (F_8, \{[18,22]\}), (F_{11}, \{[18,22],[22,6]\}), (F_3, \{[22,6]\}), (F_9, \{[22,6]\})\}$. Notice that in $\mathcal{E}_1$, F_{10} and F_{11} are acceptable together. This happens because the intervals they happen are different while in $\mathcal{E}_2$ only F_{11} is acceptable. This is because in interval $[18, 22]$ there is an attack between them.

The next part of the approach – called global selection – aims to determine the degree of fulfilment of activities. Given that a fragment is associated with a goal, a set of fragments can be regarded as a set of goals. Since a set of goals determine an activity, we can base on the set of fragments for identifying completely performed activities or having clues about the execution of possible activities. In our example, we have that all the activities were completely identified; however, we can imagine that, for example, F6 was not perceived. In that case, we would only have a clue about *having dinner*.

2 Results Discussion

We presented an approach for activity reasoning, which extends TAF approach to support defeasible activity reasoning. (Nieves, Guerrero, and Lindgren 2013) and (Morveli-Espinoza, Nieves, and Tacla 2021) used argumentation for determining inconsistent activities from a set of fragments. In their approaches, all the perceived fragments are analysed together as they happen at the same time and without considering their durability. However, the activities a human performs may happen at different times and have different duration, which should be reflected in the reasoning about human activity. Such problem is tackled in this work.

The results of this work can be used in explicability or planning support. In explicability, we can base on fragments and their relations to explain why two activities are different and/or inconsistent. We can also use fragments as clues to try to explain what goal a person likely wanted to achieve. As clues, fragments can be used to guide planning and give support a person to finish an activity. Finally, we aim to study and extend our approach as part of a symbolic-neuro architecture.

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