

# Aspectual Reasoning in LFG – A Computational Approach to Grammatical and Lexical Aspect

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**Introduction:** This paper addresses the topic of aspectual reasoning based on deep linguistic parsing in computational linguistics. To date, even well understood phenomena like the imperfective paradox are not incorporated into systems for computational reasoning. We present a computational semantic representation based on state-of-the-art formal analysis of grammatical aspect, with a focus on imperfective aspect, and Aktionsart. We propose to treat the imperfective and its instances (e.g., progressive, habituals) as universal quantifiers over situations. This is supplemented by a treatment of inner aspect (Aktionsart) inspired by Ramchand’s (2008) first-phase syntax. We translate the insights gained from these works into a semantic representation formalism that is based on AKR semantics (Bobrow et al., 2007), the computationally most fleshed out semantic formalism for LFG. The result is a hybrid approach influenced by both event structure (Krifka, 1992; Parsons, 1990; Vlach, 1981) and quantificational approaches (Arregui et al., 2014; Cipria and Roberts, 2000; Rivero and Arregui, 2010) to analyzing the imperfective. For this we take inspiration from Hallman (2009).

**Theoretical background:** The perfective/imperfective distinction sometimes overtly expressed in terms of grammatical aspect provides a fairly well understood picture of inference patterns. The perfective aspect allows for a culmination inference, i.e. the inference that a certain event has taken place in its entirety. On the other hand, a subset of what is generally classified as imperfective markers, namely those categories that invoke an *ongoing* interpretation do not commit to the culmination of an event. Assuming the English simple past has a default perfective interpretation this leads to the inference pattern in (1a).

(1a) and (1b) express different inference patterns based on further properties of the VP, in particular, its Aktionsart. The most general distinction in that regard is the notion of telicity which is true of predicates with an inherent endpoint. *(To) draw a circle* is telic since it has a clear endpoint when the circle is completely drawn. Linguistic expressions that do not license a specific endpoint, atelic predicates, such as for example *(to) push a cart* do not entail a concrete endpoint. They do not follow the inference pattern illustrated in (1a). This is known as the imperfective paradox (Dowty, 1977).

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|-----|----|--|-----|----|------------------------------------|------|
| (1) | a. | John was drawing a circle $\nrightarrow$ | (2) | a. | John draws circles. $\nrightarrow$ | HAB  |
|     |    | John drew a circle.                      |     | b. | John is drawing a circle.          | PROG |
|     | b. | John was pushing a cart $\rightarrow$    |     |    |                                    |      |
|     |    | John pushed a cart.                      |     |    |                                    |      |

- (3) John does push-ups for exercise. (Deo, 2009)

The first part of this paper deals with addressing the imperfective paradox illustrated above. However, there are two major subcategories of imperfective aspect: categories that describe ongoingness (such as the progressive) and categories that describe habituals, e.g. the simple present in English (Comrie, 1976). In principle, the habitual expresses regularly repeated actions or habits. This is illustrated in (2). However, there are fringe cases where it simply describes a ability, or other property, without the underlying action ever being actually executed, e.g., *This machine crushes oranges, when turned on* is true of an orange-crushing machine even if it never has been turned on (see Fara (2005) for some discussion).

Ultimately, all imperfective interpretations (arguably) share the intuition that some modal component is involved. The traditional analysis of the progressive makes  $PROG(P(e))$  is a modal operator which is evaluated true if the event  $e$  continues in all accessible worlds up to its culmination (Dowty, 1977). The exact nature of the accessibility relation has been a topic of debate in the work following Dowty (Hallman (2009); Landman (1992); Portner (1998); I refer to Portner (1998) in particular for a discussion of the modal approach to the progressive). In this paper, I propose a strictly linguistic accessibility relation to be specified below.

Similarly, the habitual can be modeled as a quantifier. However, in this case it does not make sense to quantify over worlds, since at least some instances of what the habitual denotes are part of the actual world. For example a sentence like (2a) assumes that for every characteristic part of the actual world (or the topic situation), in that part John draws circles (Cipria and Roberts, 2000). This part of relation can be instantiated via time intervals (Deo, 2009) or via situations (Cipria and Roberts, 2000; Rivero and Arregui, 2010). As pointed out before, the habitual also quantifies over hypothetical situations, thus we ultimately model it similarly to the *progressive* as quantifier over situations, as has been done in the previously cited work on quantificational accounts of the imperfective. The difference between the progressive and the habitual is then simply the type of accessibility relation they invoke (Rivero and Arregui, 2010).

**Implementation in AKR semantics:** As stated above, the goal of this paper is to implement the aforementioned constructions within the semantics underlying Abstract Knowledge Representations (AKRs). AKRs are based on contextual inference logic, a semantic formalism concerned with providing a semantic representation that is feasible for reasoning tasks (Condoravdi et al., 2003). In particular, it has contributed to the modeling of modal components and negation. It constrains the computational complexity of such constructions by introducing a skolemized meaning representation. In this framework a sentence like the one in (1a) may be represented as in Figure 1.

<p>Conceptual Structure:</p> <pre> definite(John:1) subconcept(draw:6,[draw-4,...]) role(Theme,draw:6,circle:13) role(Agent,draw:6,John:1) subconcept(John:1,[male-2]) role(cardinality_restriction,John:1,sg) subconcept(circle:13,[circle-1...]) role(cardinality_restriction,circle:13,sg) </pre>	<p>Contextual Structure:</p> <pre> context(t) top_context(t) instantiable(John:1,t) <b>instantiable(circle:20,t)</b> instantiable(draw:10,t) </pre>
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Figure 1: Traditional AKR: John was drawing a circle.

The primary goal of AKR semantics is to provide a basis for Entailment and Contradiction Detection (ECD) for modal reasoning as e.g. necessary in propositional attitude verbs with different factivity presuppositions (e.g. know vs. believe). For this purpose, an AKR representation consists of a conceptual structure which carries information necessary for detecting paraphrases and semantic relations (e.g. argument, theme,...) and a contextual structure which describes contexts which consist of commitments to the existence of certain objects that are available from the conceptual structure. The top context thereby corresponds to what is assumed to exist for the sake of the utterance (comparable to the actual world in possible world semantics). The concepts *John*, *circle* and *draw* are instantiated in the actual world in Figure 1. Considering the meaning of the progressive this is not exactly what we want.

**Imperfective in AKR:** To account for the progressive we require a hypothetical context, introduced by the main verb, in which the *drawing* situation is described as a whole (see Figure 2). However, we also require that some part of that situation is true in the actual world. After all, some observable process is required for the progressive to hold. In AKR contexts can be lifted into their governing context, raising all the commitments made in the embedded context to the governing context. This is not what we want in the case of the progressive. We only want to raise part of the modal context to the actual world, namely that part, which describes what is currently ongoing. In the running example of this abstract this is the *drawing* commitment. I propose, that a *concept lifting* relation which raises commitments rather than contexts is an appropriate tool to reach this goal. This is illustrated in the examples below (Figure 2 & 3). This does not exclude the possibility that the eventuality takes place in its entirety, since the context relation is an instance of an *averidical* relation. This means there is no commitment to whether or not the embedded context also holds in the top context.

```

context(t)
context(ctx:draw)
context_relation(t,ctx(draw),
                crel(Progressive))
concept_lifting_relation(t,draw)
instantiable(John,t)
instantiable(draw,t)
instantiable(circle,t)
instantiable(John,ctx:draw)
instantiable(circle,ctx:draw)
instantiable(draw,ctx:draw)

```

Figure 2: John was drawing a circle.

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context(t)
context(ctx:push)
context_relation(t,ctx(push),crel(Progressive))
concept_lifting_relation(t,push)
concept_lifting_relation(t,card)
instantiable(John,t)
instantiable(push,t)
instantiable(card,t)
instantiable(John,ctx:push)
instantiable(push,ctx:push)
instantiable(card,ctx:push)

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Figure 3: John was pushing a cart.

We base this idea on accounts that model the imperfective as universal quantifiers over situations (Arregui et al., 2014; Cipria and Roberts, 2000; Rivero and Arregui, 2010). The introduction of an embedded context thereby equates a universal quantification over situations. The modal base is modeled in terms of the *context relation*. The modal base for the progressive can be understood in such a way, that it only selects those worlds where an appropriate part of the situation can be instantiated in the actual world. On the other hand, the habitual modal base does not make such a commitment. The approach inherits further benefits from AKR in particular by means of the conceptual structure in that it provides access to contexts that are described by similar concepts.

The two different representations in Figure 2 & 3 raise an important question coming back to the imperfective paradox: Which commitments are actually raised to the governing context? Apparently, they are different for the achievement in Figure 2 and the activity in Figure 3. It is not feasible to write a function from f-structures to conceptual structures directly. As stated before, the difference in the examples above lies in the Aktionsart of the V. For this purpose, we need a principled representation of the abstract semantic properties (those properties that apply independently of anchoring in space and time) pertaining to the inner aspect or Aktionsart of V.

**Proposal II – The syntax/semantics interface:** In this paper we model inner aspect via a representation inspired by Ramchand’s (2008) first-phase syntax (FPS). In this type of analysis, elements denoting eventualities in the sense of Bach (1986) are decomposed into three different stages. An initial stage, a process stage and a result stage. An eventuality doesn’t have to denote all three stages. Thus, a (simplified) FPS representation of (to) draw a circle and (to) push a cart would look something like (4).

- (4) a. (to) draw a circle < init, proc, res >  
 b. (to) push a cart < init, proc >

The gist of the analysis is as follows: The progressive only instantiates the process stage of an event at the top context. Furthermore, it generates a hypothetical context which describes the eventuality as a whole. Informally, the top-context then would be a part of the hypothetical context. This hypothetical context would correspond to the perfective interpretation which also instantiates the whole structure. In cases where there is no concrete result this does not make a difference in terms of instantiability between perfective and imperfective. Thus, this class of verbs does satisfy the inference from imperfective to perfective. On the other hand, in predications with appropriate result stages the result is not instantiated in the actual world. Thus, the inference from imperfective to perfective fails. This covers the inference patterns of the imperfective paradox.

**Additional remarks:** The beauty of the traditional AKR system is that the general nature of concepts naturally allows for various inferences based on knowledge represented in term of linguistic units (Condoravdi et al., 2003). Thereby, contexts which instantiate concepts may be interpreted as possible worlds. The approach outlined here interprets contexts as situations, which makes contexts sensitive to notions of temporality and causation. Elaborating the whole scope of this proposal in this abstract is not possible, however, one question that needs to be addressed is the extension of concepts in the actual world. This is an issue also discussed in event-structure approaches to the progressive (Krifka, 1992; Parsons, 1990; Vlach, 1981). Some researchers argue that parts of objects can be referred to in terms of the same linguistic concept as the whole thing (Bach, 1986; Link, 1998). However, Hallman (2009) argues that there is a discrepancy between events and theme objects, namely that the latter has a non-partitive analysis. For us this would mean, that e.g. the concept circle does not refer to partial circles. We obviously take this stance in this abstract.

**Summary:** This paper provides a hybrid solution to modeling imperfectivity combining elements from the quantificational, modal approach and the event structure approach. By doing so, we circumvent the highly contextual nature of modals to a reasonable extent. Such an approach has been shown to be feasible in the domain of automated reasoning. For the purpose of this paper, we treat tense and aspect as orthogonal issues, however, future work aims at providing a time sensitive treatment of contextual structures.

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