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

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Abstract

This paper provides a semantic analysis of grammatical aspect built on the foundation of Lexical Functional Grammar. Due to this dependency this paper will also pay attention to the morphosyntactic analysis of aspect in LFG. The main focus lies on the treatment of aspect in the computational LFG grammars produced within the Xerox Linguistic Environment. The results of this endeavour are two-fold: firstly, an evaluation of the capabilities of the English XLE grammar with respect to aspect as a grammatical feature. Secondly, a semantic theory of grammatical aspect that is couched within the broader ParTMA effort with the goal of providing a cross-linguistically viable annotation and representation of tense and aspect.

1 Introduction

The main goal of this paper is to derive a semantic analysis of grammatical aspect from LFG's c- and f-structure. The underlying syntactic representation is that provided by the English LFG grammar written in the Xerox Linguistics Environment (XLE). The semantic representation is derived via annotation rules as described in Zymla (2017a,b), which are inspired by the idea of packed rewriting, the underlying concept of the XLE transfer system (Crouch et al. 2017). This annotation is a part of the ParTMA project, which is a daughter project of the ParGram effort (Butt et al. 2002). The English XLE grammar is maintained as part of this project.

Although both tense and aspect have been acknowledged as an integral part of reasoning, corresponding efforts within the domain of computational grammar development and computational linguistics in general are rather meager. Building on the ParTMA project, I present a semantic extension of the XLE analysis of grammatical aspect. This extension serves as a foundation for a semantic representation enriched with aspect information. I set a modest benchmark for this kind of representation, namely that of being able to deal with the inference patterns underlying the imperfective paradox (Dowty 1977). This pattern is illustrated in (1). The progressive as an instance of imperfective aspect allows the inference of its perfective counterpart in some cases but not in others.

(1) a. John was drawing a circle $\not\rightarrow$ John drew a circle.
b. John was pushing a cart $\rightarrow$ John pushed a cart.

It is undeniable that there is a vast amount of literature on this topic, however, concrete implementations are lacking. In this paper, I provide an overview of the syntactic and semantic category *imperfective* and related properties and show how a computationally viable semantic representation can be acquired that allows for

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automated reasoning and that captures the inference pattern illustrated above. Concretely, the semantic representation presented here is an extension of the computational semantic formalism for deriving abstract knowledge representations (AKR) (Bobrow et al. 2007).

The paper is structured as follows: In the first part of the next section, I discuss the treatment of grammatical aspect in the ParGram grammars (Butt et al. 2002) and the English grammar in particular. In the second part of Section 2, I enrich (an idealized form of) the English grammar with aspect information in the spirit of the ParTMA annotation scheme. In Section 3, I provide an overview of the relevant semantic properties from a formal perpsective, and Section 4 fleshes out these properties in the computationally viable formalism of AKR. Section 4 also explains how the new extension of AKR covers the reasoning patterns illustrated above. Section 5 concludes.

2 Viewpoint Apsect at the Syntax/Semantics Interface

In this paper, I adopt the (very general) cross-linguistic picture for grammatical aspect features shown in Figure 1 (see Comrie (1976) for reference; Carlson (2012) for comments). I focus on imperfective aspect as a central topic of this paper.

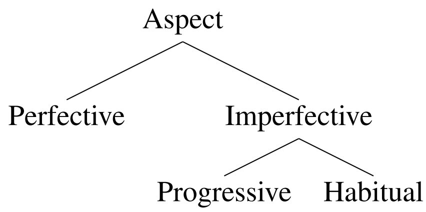


Figure 1: Aspect across languages

2.1 Morphosyntactic Realization of Imperfective Aspect in English

In languages, where there is no overt habitual/progressive distinction the imperfective may be used to express both. This is for example the case in Greek and Italian (Ferreira 2016).

Languages that do not subsume a progressive interpretation and a habitual interpretation under the banner of the imperfective often use the grammatically least marked verb form to express habituals (Dahl 1985, Carlson 2012). This is for example the case in English, where habituality is (although not exclusively) associated with present tense morphology as illustrated in (2-b).

(2) a. John is smoking a cigarette. *progressive*
b. John smokes cigarettes. *habitual*

While the progressive in (2-a) refers to an episodic or incidental interpretation (Carlson 2012), the habitual sentence expresses that John regularly smokes cigarettes. However, it does not commit to the fact that John is smoking at the time of speaking, while the progressive sentence does. This consequently means that the *progressive* and the *habitual* may be expressed in a morphosyntactically distinct manner.[1]

In the English ParGram grammar the Progressive is treated as a functional attribute. Thereby, the Auxiliary takes the role of a feature carrying element. By projecting morphological features to a morphological structure, certain dependencies are ensured, e.g., perfect vs. progressive auxiliary (Butt et al. 1999, 1996). Thus, the progressive and the perfect are analyzed as a binary feature:

(3) $\left[\text{TNS-ASP} \quad \left[\text{PROG +/-, PERF +/-}\right]\right]$

As pointed out above, the *habitual* is associated with the simple present in English. This would correspond to the following collection of `TNS-ASP` features:

(4) $\left[\text{TNS-ASP} \quad \left[\text{TENSE pres, PROG -, PERF -}\right]\right]$

However, this configuration does not automatically warrant a habitual interpretation. Thus, the habitual is correctly not treated as a functional attribute in the English ParGram grammar. In Section 3, I will capture the intuition that the habitual is a semantic category rather than a morphosyntactic one.

2.2 A Brief Note on Perfective and Perfect Forms in English

For the sake of this paper, I make explicit the assumption from the discussion of example (1) that the simple past in English has a default perfective interpretation. In the case of English this elicits an interpretation that entails a boundary point or point of completion. This is not to be confused with the perfect which is introduced by an auxiliary carrying tense information in combination with a past participle form of the main verb. In many languages similar constructions have a past tense interpretation in addition to some aspectual interpretation. This is for example the case in German where the perfect has been argued to be ambiguous (Löbner 2002, Musan 2002). The perfect in English is often treated as an aspectual category on the basis that it can be combined with the progressive. This is in line with the observation that aspect is a recursive category (De Swart 1998, de Swart 2016).

In a ParTMA style annotation scheme, tense and aspect information are disentangled allowing us to annotate fine-grained differences between languages with respect to such categories. However, for reasons of space I will not discuss the distinctive annotation of perfect vs. perfective in this paper.

[1] As some researchers point out, the progressive form in English can also mark a habitual sentence. The example below by Steedman (1997) illustrates this. The quantificational adverbial phrase "these days" enforces a habitual interpretation (section 4).

(i) I am writing a sonnet in fifteen minutes (these days).

2.3 Semantic labeling

This paper employs the strategy introduced and refined in Zymla (2017a,b) to map syntactic information onto semantic information. For our current purposes, the rules remain fairly straightforward. The labels `#g,#h,...` refer to f-structure nodes, while `#g',#h',...` refer to a semantic projection of the respective f-structure. This is not the typical s-structure assumed for Glue semantics (Dalrymple 2001), but rather a specific tense and aspect meaning structure.[2] A basic example for the domain of tense is shown in (5).

(5) `#g TNS-ASP #h TENSE past` $\rightarrow$ `#g' TEMP-REF` $t \prec t_0$

The rule simply states that past tense morphology induces a past tense interpretation. Zymla (2017b) illustrates how to resolve situations where this rule is bound to fail, namely additional rules can rewrite basic interpretations in specific contexts, resulting in a layered annotation.

In the next section, I start with a subset of rules for TA in English. The rules are illustrated below. First, a progressive label simply introduces an ongoing interpretation. Then, as already pointed out, (one) expression of habituality in English is associated with the present tense. However, this only works with *events* (see Section 3) and some information seems to still be missing. I am not committing to any particular approach at this point but see Ferreira (2016) for semantic sg/pl distinction of the verb as a pontential candidate.[3] The missing element is illustrated as "..." in the rules below.

(6) Imperfective categories (exemplified)

```
#g TNS-ASP #h PROG +_ → #g' ASPECT impv,
                        #g' ASPECT-RESTR ongoing

#g TNS-ASP #h TENSE pres,
#h PROG -_,#h PERF -_,
#g' ASP-CLASS event,...    → #g' ASPECT impv,
                             #g' ASPECT-RESTR hab
```

With respect to perfective constructions, I only make use of the simple past with a perfective interpretation. For this purpose, the following rule suffices for the understanding of this paper.

(7) Perfective category (exemplified)

```
a. #g TNS-ASP #h TENSE past,
   #h PROG -_,#h PERF -_
                        → #g' ASPECT prv,
                        #g' ASPECT-RESTR unspec
```

[2]Reconciling the two structures in a computational Glue approach is left for future work since it is orthogonal to the present paper

[3]See also Bertinetto & Lenci (2012) for a more general overview.

The choice for the semantic labels is partly inspired by the structure in Figure 1. However, it is primarily affected by the specific choice of semantic analysis for viewpoint aspect (section 3). This means that, in the next section, the exact semantic interpretation of the labels above is illustrated. As is typical for annotation in terms of semantic labels, multiple semantic theories can make appropriate use of the given annotation to generate semantic representations (Ide & Pustejovsky 2017). In this paper, I opt for a computational semantic formalism developed specifically for LFG, namely Abstract Knowledge Represenations (AKR) (Bobrow et al. 2007). However, I motivate the computational analysis in terms of formal semantic insights. These take the center stage in the next section.

3 Interpreting the Semantic Annotation

In the previous section I provided a set of semantic labels which are derived from specific syntactic configurations. In this section, I will discuss a semantic composition process that incorporates the semantic aspect annotation.

So far, I have contrasted imperfective syntactic and semantic categories with perfective categories. As pointed out in the introduction, the perfective is generally associated with linguistic expressions that describe a completed event. Completion is a property of *telic* predicates – the property of having an inherent endpoint. In this paper I take the stance that telicity is a conceptual property that is independent from grammatical aspect, which is associated with temporal boundaries. The following examples (8) and (9) by Depraetere (1995) summarize this. They are to be read as follows: If a predicate with an inherent endpoint reaches its endpoint, it is automatically temporally bounded by that endpoint. If the endpoint is not reached, then there is no temporal boundary. On the other hand, expressions with no inherent endpoint (e.g., states such as *John loves Mary* or processes such as *John is drinking beer*) can either be temporally bounded or unbounded.

(8) +inherent/intended endpoint
  a. + endpoint reached: + temporal boundary
  b. - endpoint reached: - temporal boundary

(9) - inherent/intended endpoint
  a. + temporal boundary
  b. - temporal boundary

I assume that the perfective is a boundary operator in the spirit of Depraetere (1995). However, what does it apply to? Let us start with a three-way distinction for situations: states, processes, and events (de Swart 2016, Filip 2012).

States and processes have no inherent intended enpoint, while events do so. This means applying the perfective to an event results in an event description of which the event's result is a part of, according to Depraetere (1995). A popular set of theories following Reichenbach (1947) analyses grammatical aspect as a

		durative	change	endpoint
	state	+	-	-
process	activity	+	+	-
event	achievement	-	+	+
	accomplishment	+	+	+

Table 1: Vendler (1957) classification from Filip (2012)

relation between the reference time, i.e., the time a linguistic expression refers to and the run-time of the event or eventuality time. Steedman (1997) points out that many theories fall into a similar schema, which I also follow. A refinement of Reichenbach's (1947) analysis provided by Klein (1994) realizes this relation as a subset relation. In the following example, *R* denotes the reference time and $\tau(e)$ refers to the run time of the given event.

(10) PERFECTIVE: $\tau(e) \subseteq R$
PROGRESSIVE: $\tau(e) \supset R$

This analysis causes some issues both for the perfective and the progressive. However, as their core insights remain valid, they provide an appropriate basis for this paper. However, for the imperfective, I provide a more refined analysis based on recent advances in the formal literature to support the computational implementation proposed in this paper.

3.1 Semantic Analysis of the Progressive

Formal semantic research of the imperfective has a long-standing tradition traced back to Dowty (1977). As pointed out in the introduction, the challenge provided by the progressive form in English is encapsulated in the inference pattern in (11), repeated below for convenience:

(11) a. John was drawing a circle $\not\rightarrow$ John drew a circle.
b. John was pushing a cart $\rightarrow$ John pushed a cart.

Example (10) suggests that only part of the given event in (11-a) is described by the progressive form. The beginning and endpoint of the event in question are not *visible* (cf. Smith (1991)). However, this non-visibility is non-existence in some cases. Thus, in (12) we use an expression that implies the complete crossing of the road but this implication is defeasible, as shown by the second clause of the sentence (Asher 1992).

(12) The chicken was crossing the road, when it was hit by a truck.

Processes which do not have an inherent endpoint, as in (11-b), may be bounded (perfective) or unbounded (progressive), but their internal structure remains the same. Thus, the bounded interpretation could potentially be derived as a subpart of the progressive interpretation. This explains why the inference in (11-b) is valid.

There are two major camps when it comes to analyzing the progressive and the corresponding inferences with respect to events and processes. In the one camp, an analysis based on the part-whole structure of events as well as their NP arguments (e.g., Krifka (1998), Parsons (1990)) is proposed. In the other camp, people have provided an intensional analysis of the progressive (e.g., Dowty (1977), Landman (1992)). An extensive discussion of both camps is provided in Portner (2019).

In this paper, I opt for an analysis based on the ideas of the second camp. In particular, I treat the progressive as a quantifier over situations along the lines of Cipria & Roberts (2000) and Arregui et al. (2014), especially the latter. The reason for this is simple: It provides a unified analysis over different meanings encoded in imperfective categories that is straightforwardly implementable based on the semantic labels proposed above. Concretely, the `ASPECT` label with the value `impv` introduces a quantifier over situations:

(13) **impv:** $\lambda M.\lambda P.\lambda s.\forall s'[M(s)(s') \rightarrow \exists e[P(e)(s')]]$

M stands for an accessibility relation that functions as a modal base in terms of Kratzer et al. (1991). For the present paper, I have introduced the values `ongoing` and `hab`, which introduce an appropriate relation to saturate *M*. Arregui et al. (2014) propose, among others, the following modal bases:

(14) a. $MB_{ongoing} : \lambda s.\lambda s'.s' < s$ (s' is part of s)
b. $MB_{gen} : \lambda s.\lambda s'.$ s' is a characteristic part of s

The modal base in (14) corresponds roughly to the formalization in (10). (14-b) is provided for generic/habitual sentences with disregard of fine semantic differences (see Carlson (2012) for an overview). It is noteworthy, that s corresponds to the topic situation, i.e., the actual world. This means that, if the truth of $P(e)$ is given in s', $P(e)(s)$ is automatically true as well.

This only works under the assumption that we can concretely define characteristic parts of s. This is fairly difficult for a computational system since it involves both contextual and world knowledge. For this reason, I propose a variant of the modal base that is relative to P.[4] This accounts for certain fringe cases as well as unreliability effects (see Fara (2005)), but, more importantly, the failure of entailment between a present tense habitual sentence and its present progressive counterpart is straightforwardly captured. This topic is picked up again in Section 4.

(15) MB_{gen} given $P : \lambda s.\lambda s'.$ s' is a characteristic P situation, accessible from s.

Finally, (14-a) explains the progressive for processes, but it fails to capture the

[4] See Arregui et al. (2014) for a similar proposal for progressives.

defeasibility of the result state implication that is part of the meaning of the progressive when applied to events. For this purpose, the modal base in (16) was designed. The basic idea goes back to Dowty (1977). The takeaway that is relevant for this paper is simply that the progressive form expresses a part of a complete event, the completion of which might take place in a possible world rather than the actual world. However, the progressive form is derived from a hypothetical complete form of the corresponding eventuality.

(16) $MB_{E-inertia}$: $\lambda s.\lambda s'.$ .s′ is an Event-inertia situation for s, where for any two situations s and s′, s′ is an Event-inertia situation for s iff all the events that have actually started in s continue in s′ as they would if there were no interruptions.

4 Incorporating tense and aspect information in semantic representations

In this section I provide a concrete implementation of the semantic properties outlined above. This includes both representations for verbal aspect and viewpoint aspect. The implementation is an extension of an existing semantic formalism for LFG, namely abstract knowledge representations (Bobrow et al. 2007). AKR is based on textual inference logic (Bobrow et al. 2005) and employs two different layers of meaning. The first is a conceptual layer that is inspired by Neo-Davidsonian event semantics De Paiva et al. (2007). Thus, the conceptual structure contains information about the predicate-argument structure on the one hand, but also serves as the interface to an underlying ontology in this case based on WordNet and VerbNet data. The `subconcept` facts in the example below introduce the lexical elements and their references to the ontology. The ontology consists of enumerated word senses with corresponding synsets containing information, e.g., on hypernyms, which is required for corresponding reasoning tasks. The subconcept introducing the main predicate, `draw:9` can be understood roughly as an the event variable, while the other subconcepts introduce elements that correspond to other types of entities. However, it is important to note that the elements of the conceptual structure have no extensions in the actual world. Thus, the name *conceptual structure*.

```
Conceptual Structure:
    definite(John:2)
    subconcept(draw:9,[pull-1,reap-2,trace-2,draw-4,...])
    role(Theme,draw:9,circle:19)
    role(Agent,draw:9,John:2)
    subconcept(John:2,[male-2])
    role(cardinality_restriction,John:2,sg)
    subconcept(circle:19,[circle-1, set-5,...])
    role(cardinality_restriction,circle:19,sg)
```

Figure 2: Conceptual structure: *John is drawing a circle.*

The subconcepts of the conceptual structure are instantiated in so-called contexts. Facts about this are stored in the contextual structure. This roughly corresponds to acknowledging an extension of the corresponding object in the actual world (roughly the top context) or some possible world.

```
Contextual Structure:
        context(t)
        top_context(t)
        instantiable(John:2,t)
        instantiable(circle:19,t)
        instantiable(draw:9,t)
```

Figure 3: Contextual structure: *John is drawing a circle.*

Embedded contexts are introduced by modal elements, e.g., modal verbs or propositional attitude verbs. Consider what happens when we embed the sentence above in the complement of the propositional attitude verb *know*. In this case the complementizer *know* introduces a new context anchored to its theme argument *draw*. This new context commits to a possible situation in which John draws a circle by means of the instantiation facts. However, the attentive reader will realize that the semantic representation commits to instantiation of the situation in the top context. This is a result of the factivity presupposition (Karttunen 1971) of the propositional attitude verb *to know*, indicated by the *veridical* context lifting relation in the contextual structure. In other words, by virtue of the factivity presupposition, a *veridical* context lifting relation raises the content of the embedded context to the content of the matrix context (Bobrow et al. 2007).

```
Conceptual structure:
        definite(Maria:1)
        subconcept(know:7,[know-1,...])
        role(Theme,know:7,ctx(draw:9))
        role(Agent,know:7,Maria:1)
        subconcept(Maria:1,[female-2])
        role(cardinality_restriction,Maria:1,sg)
Contextual Structure:
        context(t)
        context(ctx(draw:9))
        top_context(t)
        context_lifting_relation(veridical,t,ctx(draw:9))
        context_relation(t,ctx(draw:9),crel(Theme,know:7))
        instantiable(John:2,t)
        instantiable(Maria:1,t)
        instantiable(circle:19,t)
        instantiable(draw:9,t)
        instantiable(know:7,t)
        instantiable(John:18,ctx(draw:9))
        instantiable(circle:19,ctx(draw:9))
        instantiable(draw:9,ctx(draw:9))
```

Figure 4: AKR: *Maria believes that John is drawing a circle.*

An *averdical* context relation does not introduce a context lifting relation. For example embedded under the verb *believe*, the facts that constitute a situation where John is drawing a circle would remain only in the embedded context. This affects the reasoning about factive vs. non-factive verb. More on that in Section 4.3.

An *antiveridical* context relation is for example introduced by negation. Antiveridicality introduces uninstantiability. It is noteworthy, that only the "event" is `uninstantiable` in Figure 5. This is desired, since negation of an event only subtracts those situations from the top context where the event did not take place, whereas it does not subtract those situations where its thematic arguments exist. This is important since I use a similar line of reasoning to account for perfective vs. imperfective interpretations below.

```
Contextual Structure:
        context(t)
        context(ctx(draw:13))
        top_context(t)
        context_lifting_relation(antiveridical,t,ctx(draw:13))
        context_relation(t,ctx(draw:13),not:10)
        instantiable(John:1,t)
        uninstantiable(draw:13,t)
        instantiable(circle:20,ctx(draw:13))
        instantiable(draw:13,ctx(draw:13))
```

Figure 5: Contextual structure: *John did not draw a circle.*

For reasons of space, I simplify the structures above to simpler graph structures.[5] I remove some unnecessary information for the present purposes: I omit semantic and ontological properties from the conceptual structure where they can be derived from the example sentence. The label `top_context` is omitted from the contextual structure. Thus, the representation for *John is drawing a circle* is the following:

Figure 6: AKR: *John drew a circle.*

Veridical context lifting relations between contexts are introduced by continuous lines, while antiveridical relations are introduced by dashed lines. This is illustrated in Figure 7 by means of the sentence *John did not draw a circle*. Uninstantiable nodes are marked with `not(...)`.

[5]This idea is inspired by the actual graph-based knowledge representations by Kalouli & Crouch (2018). However, the graphs presented here are strict translations of AKR not GKR as presented in the cited work.

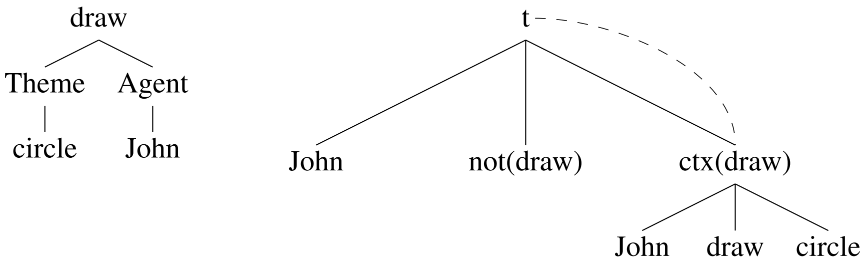


Figure 7: AKR: *John did not draw a circle.*

4.1 Enriching the Contextual Structure

The glaring issue with AKR that this paper provides a solution for is the fact that the AKR in Figure 6 does not express any temporal or aspectual information at all. This paper focusses on the analysis of aspectual properties. Temporal relations are assumed to be stored in a separate structure and to hold between contexts as well as temporal intervals. I subsume all of these elements under the label of situation in the sense of a world/time pair.[6] Temporal information will be displayed where necessary.

The goal of this paper is to change the contextual structure in AKR. Until now, the approach has been fleshed out in such a way that contexts are closer to possible worlds rather than situations in the sense that no temporal information is incorporated in them.[7] Thus, the AKR in Figure 6 can be mapped on any of these following sentences:[8]

(17) a. John draws a circle.
b. John drew a circle.
c. John is drawing a circle.
d. John was drawing a circle.
e. John has drawn a circle.

I propose a more fine grained representation that (for the sake of this paper) assumes the perfective representation as the default (see Figure 8) and the progressive is represented in a more detailed structure (see Figure 9). Both the progressive and habitual in Figure 10 introduce an intensional context. They, thus, correspond roughly to the intensional quantifiers discussed in Section 3. More concretely, the *progressive* and the *habitual* describe different relations between the `top_context` and the embedded `ctx`. The latter can be treated in the same vain as any other averidical relation, e.g., those provided by non-factive attitude verbs. The treatment of the *progressive* on the other hand is novel, yet simple. The idea is, that the whole eventuality and its arguments is embedded intensionally in an averdical relation to the `top_context`. However, the conceptual description

[6]Theoretically this approach is closer to Barwise & Perry (1981).
[7]At least without concrete temporal modifiers such as *yesterday* or *tomorrow*.
[8]Based by the entailment pattern provided by the system described in Bobrow et al. (2007).

of the event itself is raised to the `top_context`. It thus shares the conceptual structure with its embedded counterpart but behaves differently in terms of intensional reasoning. This is explained in detail in Section 4.3. In the next section, I illustrate the difference between *events* and *processes* at the level of the conceptual structure and how it affects the corresponding contextual structure discussed in this section.

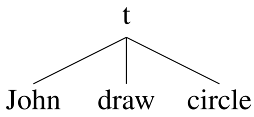


Figure 8: AKR: *John drew a circle.*

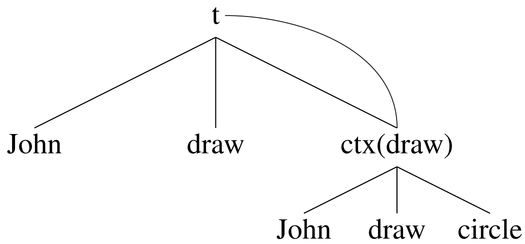


Figure 9: AKR: *John is/was drawing a circle.*

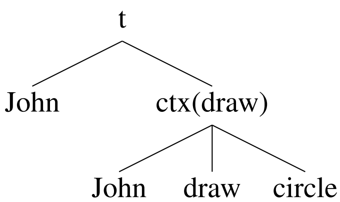


Figure 10: AKR: *John draws circles.*

4.2 Enriching the Conceptual Structure

The conceptual structure of an AKR is created from various lexical resources, in particular, WordNet and VerbNet. Those resources are (partially) compiled into a unified lexicon (Crouch & King 2005). The unified lexicon disambiguates word senses on the basis of f-structure correspondences where possible.[9]

In the previous section, I explained that the imperfective paradox arises due to the different event classes that it can apply to, i.e., events and processes. Unfortunately, this information is not straightforwardly derivable from the conceptual structure in the AKR. To remedy this, I propose to provide an extension of the conceptual structure based on decompositional event semantics. I illustrate this in terms of an an implementation of Ramchand's (2008) first-phase syntax (FPS). The template for the FPS is shown in Figure 11.

[9]The unified lexicion ascribes word senses to certain grammatical structures, e.g., `V-SUBJ-OBJ`). These are aligned with the subcategorization frame employed by the syntactic component. Even then the output is often highly ambiguous since multiple word senses might be associated with the same subcat frame. For reasons of space I ignore this issue for the most part.

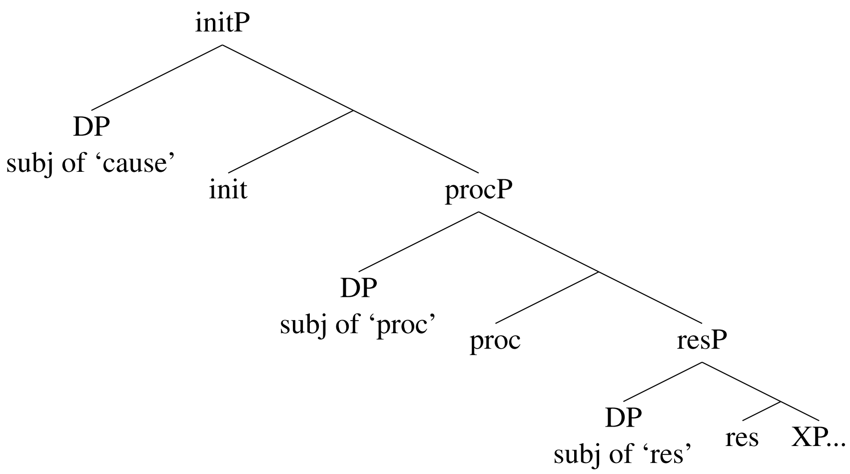


Figure 11: First-phase-syntax template (Ramchand 2008)

As the template illustrates, the FPS assumes three different syntactic heads containing two different elements. First consider the stages of a given eventuality: *init*, *proc*, and *res*. *init* and *res* are states that refer to the state before and after the change described by *proc*.[10] Second, the *subj* slots are provided for the corresponding thematic roles. The *subj of 'cause'* can be derived mnemonically from the corresponding head: it denotes the iniator. The *subj of 'proc'* is generally an *undergoer* and the *subj of 'res'* is the resultee. An overview of correspondences between the different sub events and the corresponding thematic roles can be found in Ramchand (2008: 98). The correspondences between FPS and aspectual class as presented above are given in (18). An eventuality, either a process or an event, is a sequence of sub-eventualities written as $< \phi, \psi, ... >$. Parenthesis denote an optional object.[11] For the present purposes a *telic argument* is quantized or describes a (finite) path. Conversely, an atelic argument is cumulative, or does not otherwise specify an endpoint (Krifka 1998).

(18) a. *Event* $\rightarrow < (init), proc, res >$
Process + *"telic argument"*
b. *Process* $\rightarrow < (init), proc >$ + *"(atelic argument)"*

This means that the syntactic structure inside *V* is as in Figure 12 for the two examples relevant to the imperfective paradox.

[10]The boundaries are not completely rigid, in fact there can be a complete overlap between *init* and *process* (Ramchand 2008). Thus, I take it that *init* includes a preparatory stage in the sense of Moens & Steedman (1988). And *proc* refers to the actual event taking place.

[11]Optional initiators are for example found in sentences like *the snow melted*, where *melt* describes a process without an active initiator (*subj of 'cause'*).

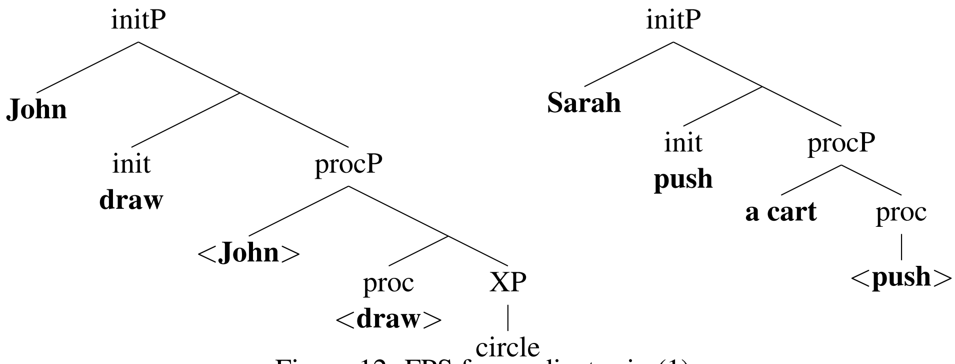


Figure 12: FPS for predicates in (1)

Given this additional structure we can define a procedure that maps decomposed events onto contextual structures as presented in Section 4.1. However, an additional step is required since neither of the predicates *draw* and *push* has a syntactically realized result state in the sense of Ramchand & Svenonius (2014). The *XP* in Figure 12 denotes an *telic argument*. Similar, to proper result states we can derive a situation that expresses the result state of *drawing a circle*, namely, the situation in which a circle has come into existence. This can be modelled in terms of *instantiability* in the case of both consumption and creation verbs. An object coming into existence becomes instantiable, and an object that is consumed becomes uninstantiable.

In the case of the creation verb *draw*, the result state is modeled as a context `ctx` in which *circle* is instantiated. By simply mapping all unique elements on to a context we achieve our default perfective interpretation which entails the achievement of the result state. From this we raise the fact that corresponds to the *procP* in the FPS to the `top_context`, following the intuition that the progressive is derived from its resultative (perfective) form we have commited to in Section 3.

The derivation of the result state has to be adapted for different possible *XP* objects such as consumables or paths. In particular paths as, e.g., in *Sarah pushed the cart to the store* provide a challenge. This is due to the fact that there is neither a conceptual nor a contextual description that corresponds to what it means to follow a path.[12] However, leaving the issue underspecified might work well enough. The perfective representation could simply entail proximity to the goal of the path, where as in the progressive variant the `top_context` which does not instantiate the *goal* corresponds to the situation in which there is no proximity between *initiator*, *undergoer* and *goal*. The specifics for various verb classes are left for future research.

[12]Zaenen et al. (2008) provide an approach to predicates of change-of-location in AKR and will be considered in future work. Thanks to a reviewer for pointing this out to us.

4.3 Inferencing

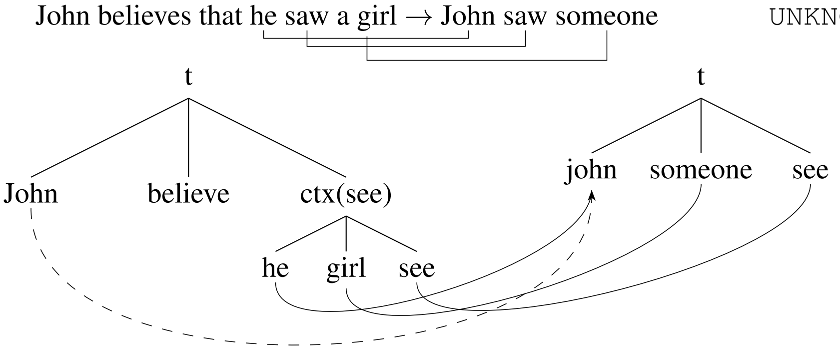
AKRs are specifically designed for inference tasks. In the next few paragraphs, I give a rough sketch of the inferencing techniques employed in combination with AKR representations (see Bobrow et al. (2007) for a more extensive explanation).

AKR uses a so-called entailment and contradiction detection (ECD) system for detecting inferences. As the name suggests it tests whether an entailment or contradiction relation holds between two linguistic expressions. The basic idea is fairly straightforward: First, the premise and the conclusion are aligned on a conceptual level. If two concepts conflict (e.g., due to negation in *a boy smiled* → *a boy did not smile*), a contradiction flag is introduced. A successful alignment is shown in (19). The concepts *John* and *saw* are identical between the sentences and thus alignment is trivial. The specific concept *girl* entails the less specific concept *someone* but not vice versa. Thus, the inference in (19) is valid, but the reverse inference is not.

(19) John saw a girl → John saw someone `YES`

The ECD not only checks for conceptual similarity but also checks for intensional reasoning by means of the contextual structure. Consider the example below. Figure (20) illustrates that, conceptually, an alignment similar to the one in (19) can be found. However, this time the premise has instantiated the concepts in an intensional context (introduced through the non-factive verb *believe*). Since non-factive verbs do not introduce a context-lifting relation, the concepts are instantiated only in the hypothetical context `ctx(see)`. Although the concept *John* is instantiated in the top context the alignment is not fruitful as represented by a dashed line.

(20) John believes that he saw a girl → John saw someone `UNKNOWN`

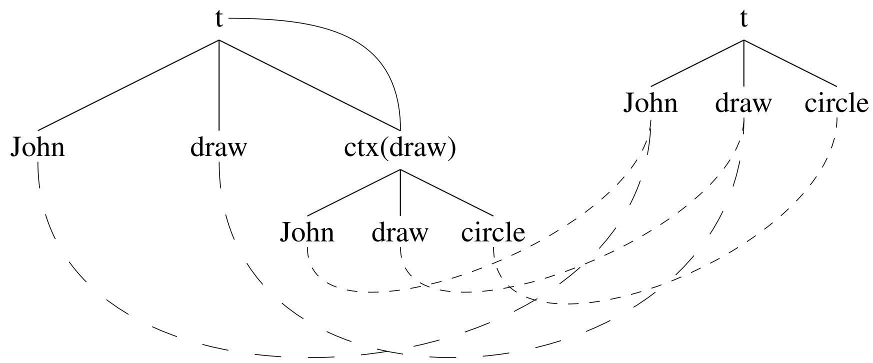


Formally, the system calculates inferences by deleting aligned concepts if their contexts are compatible. This means, in (19) all concepts are deleted since they belong to the same context. The result is an entailment relation. In (20) the system will not delete the aligned facts since they make commitments about different contexts. The inference in (20) is not valid. Contradictions are introduced by specific flags. As this explanation suggests, ECD has three possible output states: `YES` for entailments, `NO` for contradictions, and `UNKNOWN` for all other cases.

4.4 Reasoning with aspect

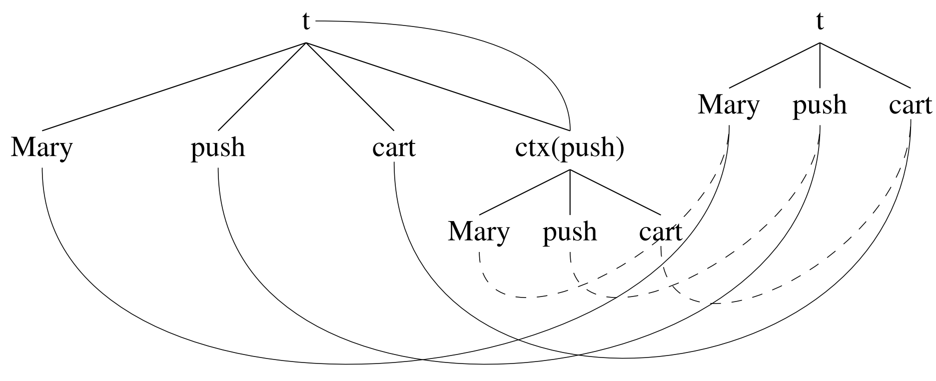
Example (21) illustrates why the inference from an event in the progressive form such as *(to) be drawing a circle* to its simple past counter part fails: The conclusion in (21) may be fully aligned with the intensional context introduced by the progressive. However, due to the mismatch between `top_context` and embedded context, this alignment does not lead to the deletion of the corresponding conclusion facts. Furthermore, the conclusion can only be partially aligned with the top context of the premise. Thus, based on this alignment the corresponding facts in the conclusion will not be fully deleted either. The fact corresponding to the *circle* remain.

(21) John was drawing a circle → John drew a circle `UNKNOWN`



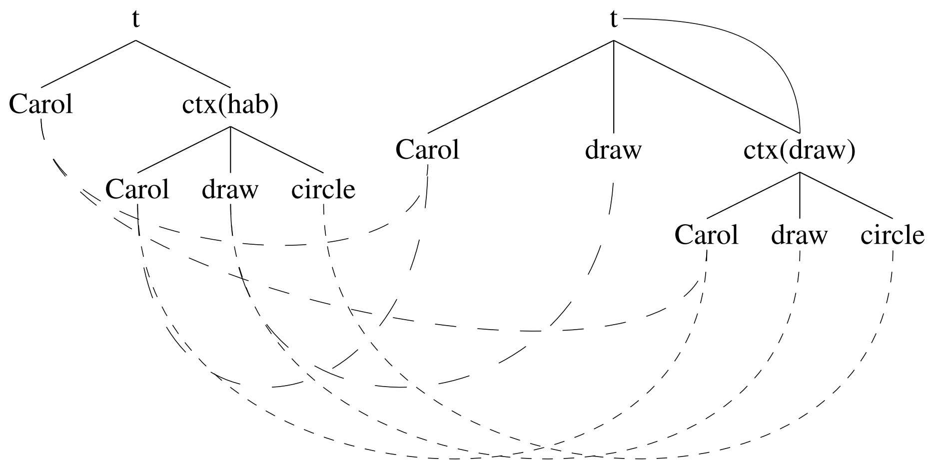
Compare this to example (22). Applied to an achievement the progressive form provides a different `top_context`. Now, the conclusion is fully entailed in the premise conceptually as well as contextually, which leads to entailment detection.

(22) Mary was pushing a cart → Mary pushed a cart `YES`



The third kind of inference, which I mentioned in the beginning of the paper, is the inference from a habitual to its progressive counterpart, as shown in (23). The inference should fail as indicated. The corresponding contextual alignment seems messy but the inference ultimately fails simply due to the instantiation of *draw* in the `top_context` in the conclusion, which does not find a corresponding element in the `top_context` of the antecedent.

(23) Carol draws circles → Carol is drawing a circle UNKOWN



A challenge for the approach presented here is presented in (24). I established before, that the progressive does not commit to the fact that the corresponding event reaches its intended endpoint. However, the circumstances can be modified, for example, by the conjunct added in the premise in (24) to the effect that the intended endpoint and consequently the result state can never be reached.

(24) *The chicken was crossing the road*, when it got hit by a truck → *The chicken crossed the road* UNKNOWN

However, I argue that this is not a problem of the present approach but rather an issue of incorporating world knowledge into the inference system. In fact, whether the inference is valid or not is still unknown because it is not clear whether the accident simply changes the path of the chicken or actually prevents it from achieving its goal.

5 Conclusion

In this paper I have laid the groundwork for aspectual reasoning with help of computational LFG methods. I draw from existing resources, in particular the bridge system developed at PARC (Bobrow et al. 2007). By introducing additional layers of semantic information, such as temporal and aspectual information, the contextual structure of AKRs has been made substantially more expressive. The change can be understood as a movement from contexts as possible worlds to contexts as world/time pairs or situations.

This system works under the precondition that the semantic representation (based on Neo-Davidsonian event semantics), from which an AKR is derived, is enriched in terms of decompositional event semantics à la Ramchand (2008). This information together with the information provided by the lexical resources incorporated in the PARC bridge system allows for the implementation of a principled way for treating tense and aspect that captures the basic inference patterns observed in the literature.

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