Cross-Linguistically Viable Treatment of Tense and Aspect in Parallel Grammar Development

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Abstract

This paper reports on a robust treatment of tense and aspect that is designed for computational purposes such as the crosslinguistically broad ParGram effort. Our ParTMA (Parallel Tense/Mood/Aspect) project builds on theoretical insights within formal semantics and pragmatics, but places them on a broader crosslinguistic footing and develops a computationally viable interface between morphosyntax and semantics/pragmatics. We illustrate how our approach works with respect to selected phenomena that include tense underspecification, morphosyntactic variation and sequence of tense effects.

1 Introduction

The work reported on here is part of a larger project on developing a crosslinguistically and computationally viable annotation scheme for tense/aspect phenomena. The work was originally inspired by work within the ParGram effort Butt et al. (2002, 1999), which included several discussions on how to deal with tense/aspect. One problem faced by ParGram was that the semantics of tense/aspect could not necessarily be "read off" the morphosyntax of a given expression. Another was that theoretical linguistic work on tense/aspect up until recently tended to engage only with a small minority of the world's languages and therefore with only a narrow sample of the overall crosslinguistic patterns (Giorgi & Pianesi, 1997; Kamp & Reyle, 1993; Klein, 1994; Smith, 1991).

On the other hand, typological studies have amply demonstrated the rich variety of expression across tense and aspect categories (e.g. Comrie 1985; Croft 2012; Dahl 1985) and the existing formal approaches have shown that tense and aspect is expressed via complex interactions across morphology, syntax, semantics and pragmatics, whose individual parts have not been fully understood (for an overview see Tonhauser (2015)).

Consider the following example from the "Scorpion Story" often used in typological or language documentation research.

(1) a. Once a scorpion was standing by a river.
be.Past stand.Prog
(English)

b. ek t^haa bicc^{h}u jo daryaa ke kinaare k^{h}aṛaa t^haa
one be.Past scorpion Rel river Gen.Obl bank stand.Perf be.Past
(Urdu)

c. Konon ada seekor kalajengking berdiri di pinggir sungai
once there.is a scorpion stand on edge river
(Indonesian)

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This example illustrates three different ways of encoding both tense and aspect. The situation of a scorpion standing by a river bank sometime in the past is encoded periphrastically in English. A 'be' auxiliary inflected for past tense is combined with a main verb that carries the progressive *-ing* morphology (*AUX + V+ing*). In Urdu, the situation is expressed via a perfective morphology on the main verb in combination with a past 'be' auxiliary. In Indonesian, on the other hand, there is no overt tense or aspect marking. However, the initial expression 'Konon'(trans. *it is said, that*) signals at a modal, back-shifted context.

Given this type of variation in the expression of tense/aspect, a central challenge, particularly from a computational perspective, is the formulation of a crosslinguistically applicable mapping from morphosyntactic cues to semantics and pragmatics. We sketch such a mapping in this paper and show how it fits in well with the existing LFG and ParGram architecture.

The paper is structured as follows: The next section provides more background on tense and aspect. In section 3 we present our own proposal for the treatment of tense and aspect, focusing especially on aspects that pertain to grammar engineering. In section 4 we use the novel analysis of tense and aspect to explore syntactic, semantic and pragmatic variation in the categories of tense and aspect, thereby providing a more detailed understanding of the inner workings of the new proposal. Section 5 sums up the paper.

2 Tense and Aspect in LFG and ParGram

Research on tense and aspect encompasses a vast domain. Given the confines of this paper, we leave aside related areas such as evidentiality and mirativity. We also focus mainly on tense in this section and open up the analysis to aspect as the argumentation in the paper unfolds.

2.1 ParGram

The ParGram effort provided the basis and the inspiration for the overall project of devising a crosslinguistically and computationally viable system for calculating tense/aspect. The ParGram effort dates back to 1996, with German, English and French constituting the original grammars (Butt et al., 2002, 1999). Over the years, grammars for a typologically rich set of languages were added within ParGram and a parallel treebank, the ParGramBank, began to be compiled (Sulger et al., 2013). ParGramBank is hosted via the INESS treebanking infrastructure (Rosén et al., 2009; Rosén et al., 2012). The languages currently covered by ParGram grammars of varying sizes are: English, French, Georgian, German, Hungarian, Indonesian, Malagasy, Norwegian, Polish, Tigrinya, Turkish, Urdu, Welsh, Wolof.[1]

[1]There are also Chinese, Korean and Japanese grammars; however, these are not currently publicly accessible.

Given that the ParGram grammars focus on modeling the morphology and syntax of a language, but that the morphology and syntax of a language does not completely determine the semantics and pragmatics of tense and aspect, the strategy adopted within ParGram was to encode the morphosyntactic information provided by the language at f-structure, but not to attempt putting this information together in any more sophisticated way (i.e., piecing together the overall information of periphrastic expressions).

"The f-structure thus now encodes exactly those distinctions which are made overtly in each of the languages without attempting to second guess a semantic analysis [...]. (Butt et al., 1999, p. 69)"

The overall goal of this strategy is to provide a morphosyntactically informed basis for further semantic processing.[2] But this semantic/pragmatic interpretation of tense and aspect categories hinges on linguistic properties that go beyond what can be inferred from the morphosyntax.

2.2 ParTMA and Temporal Semantics

As part of our larger project, we have been extending the ParGramBank with sentences taken from the testsuites constructed by Dahl (1985).[3] The crosslinguistic survey compiled by Dahl (1985) elicits sentences by providing a specific context that tests for variation in the expression of tense/aspect.

As a case in point supporting the ParGram strategy to date, consider the two sentences from Norwegian (2a) vs. Indonesian (2b) which are provided as appropriate given the context formulated in (2).[4]

(2) [Q: When you visited Peter yesterday, what did he do after you had dinner? ANSWER:]

a. Peter skrev et brev
Peter write.Past a letter
'Peter wrote a letter.'

b. Peter akan menulis se.buah surat
Peter FUT AV.write one.CL letter
'Peter wrote a letter.'

The contrast in morphosyntactic encoding of parallel semantics is obvious: (2a) uses a past tense marker while (2b) uses a future tense marker. But both roughly correspond to the English sentence 'Peter wrote a letter.', as reflected in the translation. However, the parallelism is only apparent. To understand this we have to

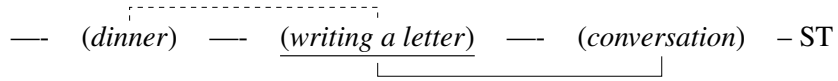
[2]Our proposal thus stands in contrast to earlier approaches which encoded semantic features related to the interpretation of tense and aspect at the level of f-structure. One such approach is Glasbey (2001), who advocates including semantic features in the syntactic lexicon.

[3]For this, we relied heavily on the ParGram grammar writers and would like to thank them again for providing both data and banked analyses to the ParTMA treebank.

[4]AV = active voice, CL = classifier, FUT = future

examine the meaning the two sentences express. Focusing on the temporal allocation of the eventuality *writing a letter*, two temporal relations are essential if one takes into consideration the question given in the conversation context. First, the relation to the speech time (ST) and second the relation between *writing a letter* and the dinner, which is already situated in the past by virtue of the temporal modifier *yesterday*.

(3) Temporal progression chart:



An analysis of the facts outlined above leads us to the conclusion that in Indonesian the relation between the dinner and the writing in the context is highlighted by the future morphology, while the relation to the time of the conversation remains implicit. On the other hand, the relation that is overtly expressed in Norwegian holds between the 'writing' eventuality and the time of the conversation. Crucially, both of the tenses here have an antecedent in the previous discourse and relate different temporal variables.

This minuscule case study of comparing just one instance of tense morphology has shown that several layers of linguistic analysis must be taken into consideration in the analysis of tense: morphosyntax, semantics and pragmatics.

2.3 Tense/Aspect Semantics in LFG

The example from Indonesian showed that we need to deal with several different types of tenses: absolute tenses, relative tenses and complex tenses. To make this point more clearly, consider what happens when the same Indonesian sentence of (2) is uttered in an out-of-the-blue-context.

In this case, the two English examples (4b)) and (4c)) represent rough paraphrases of the two readings we could get for the Indonesian sentence. Both paraphrases contain a tense (*will* and *was*, respectively) that behave deictically (i.e., referring to the speech time), but the additional future construction *going to* in (4c)) must be interpreted relative to the past shift, just as the future marker in Indonesian in (2).[5]

(4) a. Peter akan menulis se.buah surat
Peter FUT AV.write one.CL letter
b. Tom will write a letter.
c. Tom was going to write a letter.

[5]We do not claim that either of the languages has purely relative or purely deictic tenses, although the former is theoretically more appealing since deictic tenses can be interpreted as a subset of relative tenses (Comrie, 1985).

This allows English to overtly express different temporal relations that, in Indonesian, are subsumed by one syntactic marker. This is not at all uncommon but it shows us that syntactic markers have to be carefully examined from a semantic perspective to arrive at a proper understanding of the linguistic properties they represent. With this in mind, we explore the necessary mapping from syntax to semantics in more detail.

To get a clearer picture of which elements are derived from the syntax and which elements are semantically motivated, let us investigate a small semantic typology based on the observations we made so far about English and Indonesian. We implement these insights in terms of a classical extensional tense theory, where our temporal pronouns represent Klein's topic time (Klein, 1994). Thus, we provide a lambda term that picks up a temporal variable corresponding to the topic time(TT) of the sentence and tests if it fulfills the truth conditions posed by the respective tense, which are expressed in terms of a relation with an evaluation time(ET), e.g. past tense: $TT \prec ET$, future tense: $ET \prec TT$.

(5) a. $[\![past_d]\!] = \lambda P.\lambda t.t \prec t_0 \wedge P(t)$
b. $[\![future_d]\!] = \lambda P.\lambda t.t_0 \prec t \wedge P(t)$
c. $[\![future_r]\!] = \lambda t.\lambda t'.t' \prec t \wedge P(t)$

Our preliminary analysis (to be revised) consists of two completely deictic tenses, (5a) and (5b) indicated with a *d* subscript, which are obligatorily linked to the speech time and a relative tense, (5c) marked with a *r* subscript, whose $\lambda t'$ provides a slot for a contextually salient evaluation time. In other words, the first two tenses are interpreted absolutely with respect to the speech time, while the last tense is interpreted with respect to some salient variable (which could also be the speech time). [6]

Overall this first analysis allows us to cover several types of tenses: absolute tenses, relative tenses and complex tenses. An analysis with a similar spirit is, in principle, provided by Haug (2008) for glue semantics.

2.3.1 Glue semantics and Co-Description

We believe our approach goes beyond the proposals in Haug (2008) by providing a better way of combining pragmatic inferencing with the semantic interpretation of tense/aspect. In order to demonstrate this, we examine a typical glue semantics analysis in more detail.

Glue semantics generally assumes analysis via co-description (Asudeh & Toivonen, 2009; Bresnan & Kaplan, 1987). Consider for example the following lexical entry for 'slept'.

[6]The last case, the back-shifted future tense, could be modeled in terms of an iterated tense in the spirit of Klecha & Bochnak (2016) if we assume that all temporal relations are expressed by tenses. The approach essentially combines two nodes of the type $< i, t >$ and $< i, < i, t >>$ (disregarding world variables) to a node $< i, t >$ that conjoins the two $< i, t >$ elements. In this case, we would combine the relative future tense with the past tense to yield the back-shifted reading.

(6) Lexical entry for 'slept':

a. slept V
   (↑ PRED) = 'sleep'
   (↑ TENSE) = PAST
   (↑ SUBJ) = $\uparrow_\sigma$ ARG

b. i. $\lambda x.\lambda t.\exists e.sleep(e) \wedge agent(e) = x \wedge \tau(e) = t :$
   $\uparrow_\sigma ARG \multimap (\uparrow_\sigma TT) \multimap \uparrow_\sigma$

   ii. $\lambda P.\lambda t.P(t) \wedge t \prec ET : ((\uparrow_\sigma TT) \multimap \uparrow_\sigma) \multimap (\uparrow_\sigma TT) \multimap \uparrow_\sigma$

The co-descriptive lexical entry in (6) consists of two parts: 1) The 'syntactic part' that provides the properties necessary for building the c- and f-structure; 2) the 'semantic part' that consists of two glue formulae ((6b-i) and (6b-ii)), which can be composed into a constructor for the lexical entry 'slept'. A glue formula comprises a semantic representation on the left and a linear logic representation on the right. This guides the compositional process. For our purposes, we only need to understand the process of functional application, i.e., the substitution of variables by appropriate arguments. In linear logic this roughly corresponds to the linear implication rule $A, A \multimap B \vdash B$, which says that we can generate a resource *B* from the rule $A \multimap B$ if a resource *A* is available. In this case *A* corresponds to a element of the appropriate type and B is the corresponding result of the functional application.

The glue formula in (6b-i) serves to combine the verb 'slept' with its thematic arguments (the meaning corresponding to the subject $(\uparrow_\sigma ARG)$) and (6b-ii) is our constructor for past tense which picks up a resource of the shape $((\uparrow_\sigma TT) \multimap \uparrow_\sigma)$ and returns a resource with the same compositional properties, whose event run time, i.e. the duration of the event $(\tau(e))$, is set equal to a time interval that is restricted to the past.[7] This means that we can create a temporally restricted predicate after we have combined it with its thematic arguments, since the resulting semantic element is of the form $(\uparrow_\sigma TT) \multimap \uparrow_\sigma$, which corresponds to the premise of the linear implication $A \multimap B$ on the glue side of (6b-ii). As a result we are provided with a tensed predicate with an open lambda slot for the topic time.[8] Technically speaking, the proof is unfinished at this point with the premise: $\lambda t.P(t) \wedge t \prec ET : (\uparrow_\sigma TT) \multimap \uparrow_\sigma$.

One strategy to complete the proof is to apply an existential closure operator that is syntactically introduced by the clause-type feature: $\lambda P.\exists t[P(t)] : (\uparrow_\sigma TT) \multimap \uparrow_\sigma$. Another strategy is to let pragmatics introduce a temporal variable that is compatible with the proposition. The fact that there are multiple solutions to the problem at hand, especially with regard to pragmatic reasoning about time intervals, shows that there is more work to be done in terms of finding a constrained and principled approach towards calculating tense and aspect.

[7] The syntactic subject is projected onto a semantic argument role at the semantic structure.

[8] We simplified the approach in this case for illustrative purposes. For details see Haug (2008)

2.3.2 A Computational Approach via Description by Analysis

An alternative to the co-description approach is one generally referred to as "description by analysis" (Halvorsen & Kaplan, 1988), by which a semantic analysis is arrived at on the basis of information provided by another level of representation. For semantics, this is generally taken to be the f-structure.

The description by analysis approach tends to be the one chosen by computational applications, since it allows an abstraction away from the underlying morphosyntax and also frees the system from following strict compositionality as determined by the phrase structure analysis. Instead, a f-structural information must be placed in correspondence with semantic information, leading to the formulation of a syntax/semantics interface. This can in turn be supported by external by lexical semantic resources such as WordNet or VerbNet (Bobrow et al., 2007; Crouch & King, 2006). The benefit of this approach is that we can more easily deal with the polysemy of certain morphosyntactic constraints, as discussed below. This is therefore the approach that we adopt in our proposal.

As an example, consider polysemy in the category of tense in English with respect to two types of examples: 1) counterfactuals (7a); 2) the sequence-of-tense phenomenon (7b).

(7) a. I wish I **had** a car.
b. John said that Mary **was** sick.

The two tenses highlighted in the examples above are uses of the past tense morphology that do not strictly correspond to the expected semantics, namely, temporal anteriority. Note that both of them occur in a embedded context. Intuitively, this means the meaning of the past tense morpheme in English shifts its meaning according to the context it occurs in: the context is a combination of syntactic and semantic properties. For example, the meaning shift in (7a) from past to non-past & counterfactuality could be a result of the embedding under a bouletic modal, i.e. in contexts where desires are expressed (von Fintel, 2006).

Example (7b) illustrates the sequence-of-tense (SOT) phenomenon, which typically occurs when a propositional attitude verb inflected with past morphology governs a verbal predicate, often a stative, that is also inflected for past morphology.[9] The predicate in question then expresses tenselessness with regard to the matrix predicate. However, there seems to be some sort of temporal constraint imposed by the subjective now (the time that the attitude holder believes to correspond to the *now*) in the epistemic context of the modal component of the propositional attitude verb. In other words, the semantics of the matrix predicate – coincidentally again a modal component – affect the temporal interpretation of the embedded predicate (Abusch, 1997). More specifically, the epistemic now of the worlds over

[9] See Kusumoto (1999) for a discussion of the 'stative' requirement of embedded predicates. In our eyes, the arguments are a bit shaky, thus in this paper we assume that, typically, only statives can express the SOT phenomenon. Some accounts describing the SOT phenomenon hinge on this assumption (see Altshuler & Schwarzschild (2012)).

which the modal quantifies, the doxastic alternatives, is an upper constraint for the temporal variable that the past tense of the embedded predicate adheres to. Thus, SOT expresses a simultaneous reading with regard to the matrix event in addition to a back-shifted reading where the embedded tense shifts back the event's topic time relative to the epistemic now, which corresponds roughly to the topic time of the embedded event. The sentence in (7b) can thus be understood as having two readings as a result of deleting or weakening the embedded past tense.

In conclusion, both the syntactic context and semantic properties of the surrounding context affect the interpretation of tense markers, which are themselves thus inherently polysemous/underspecified. This is awkward to model in a co-descriptive approach, as it entails anticipating the various possible readings within the lexicon and/or the morphology. Under the description by analysis approach, the interpretation of tense marking can be modeled more intuitively as the result of a complex interacting system of syntactic, semantic and pragmatic information.

3 Our Proposal for the Syntax-Semantics Interface

In this section we propose an eventuality structure that encodes only the temporal (and potentially modal) dimension of an event provided by a (partial) f-structure. In other words a semantic representation of f-structure nodes that introduce an event variable and thus a subset of the semantic structure employed in glue semantics.

This architecture is proposed as a direct consequence of our overall aim: to have an annotation scheme for tense and aspect that is computationally and cross-linguistically viable. Given that the morphosyntactic expression of tense/aspect varies across languages and that languages employ different semantic strategies, e.g., as we saw for English vs. Indonesian, the design decision here is to avoid problems of compositionality and instead provide an inter-operable annotation that can be read off of LFG syntactic representations in a first pass.

This in principle means that tense and aspect is treated as a mostly independent system that is connected to other semantic systems via morphisms. This plays a role, for example, when dealing with lexical aspect where there is a crucial relation between objects in the nominal and objects in the verbal domain (Krifka, 1998). Exploring these mathematical relations goes beyond the scope of this paper. Here, we focus strictly on the representation of tense and aspect categories as mappings from syntax to semantics and as semantically and pragmatically constructed meanings.

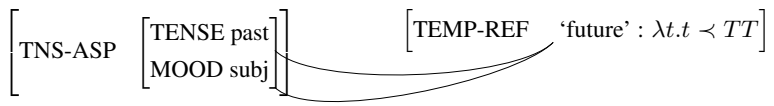
3.1 Semantics

The first step is to capture the semantic intuitions that we have worked out in section 2. The mapping principles from f-structure to an eventuality representation are encoded in terms of inference rules and represent the syntax/semantics interface. For example, assume we want to map the syntactic feature TENSE 'past' to a semantic representation of past tense. For this, we use a implication rule *TENSE*

'past' $\rightarrow$ *TEMP-REF 'past'*, as in (8). A implication rule holds as long as it is not over-written by a stronger rule. The strength of an implication rule $\alpha \rightarrow \beta$ is determined by the number of premises it has. The more premises, the stronger the rule. Thus, for a specific feature and value ϕ there might be an alternative annotation of the same feature with a different meaning ϕ' and the two variants originate from different inference rules: $\alpha \rightarrow \phi$ and $\alpha \wedge \beta \rightarrow \phi'$. In this case, the latter rule would apply since it is more specific than the former. This will be illustrated more concretely in section 4.[10]

(8) 

Consider for example the sentence: *A child was born who would be king.* The past tense of the first verbal predicate could be parsed and placed in correspondence with a semantic representation as in (8). The tense marked on the verb *would* could be represented in the syntax as in (9) (based on Abusch (1998)). However, our tense rule, then, would give us a false semantic interpretation, since it also allows for future time reference with respect to the speech time (see Dowty (1982) for discussion). Thus, we need to create a stronger rule that replaces the general tense rule with a relative future tense, as shown in (9).

(9) 

This type of rule can now be used to relate different semantics to different types of syntactic contexts, generating primary meanings.

3.2 Pragmatics

In this section, we turn to the role of pragmatics in the interpretation of tense and aspect. As pointed out by Haug (2008), pragmatic reasoning must build on our first semantics pass.

"[...] The truth-conditions which derive from the semantics cannot be overridden by pragmatic inferencing. (Haug, 2008)"

For us this means that the role of pragmatics is to restrict the available readings based on contextual inference. Consider the zero-marked Indonesian example (10).

(10) [The most recent market happened yesterday.
Q: Have you met Peter before?]

saya bertemu Peter di pasar (itu)
I MID-meet Peter at market (that)
'I met Peter at the market.'

[10]This principle is inspired by the maximize presupposition constraint presented in Heim (1991) and applied to the domain of tense, e.g., in Cable (2013).

Since there is no overt tense and aspect marking, there is no information that can be placed into correspondence with any meaningful tense value at the semantic level. All that can be concluded is that the temporal reference is unspecified, as shown in (11).

(11) $\left[\text{TNS-ASP} \quad \left[\text{MOOD indicative}\right] \quad \left[\text{TEMP-REF} \quad \text{`unspec'} : \lambda t.t\right]\right]$

In our example, it is the context which resolves the temporal location of the 'meeting' event, namely the market that took place yesterday. An essential part of resolving temporal relations is determining identity relations between eventualities.[11] There are two instances where this is important in (10). The identity relation between the 'meeting' event in the question and the 'meeting' event in the answer and the identity relation between the market in the discourse context and the market in the answer. How can we anchor the resolution of this identities in the formal system presented here?

First, let us make a very general statement: Finite verbs have a location in time. This location can be expressed as a temporal relation between the corresponding event and the evaluation or speech time. Thus, let us make a bolder claim: Tenseless finite verbs inherit a deictic tense from the context.[12] For the present purposes we accept this without argument.

Given this assumption, the question that must be resolved is how this inheritance can be modeled in our system? As shown in (11) the expressiveness of the explicit mapping from syntax to semantics is basically zero. However, in the given context, (10) has a clear meaning. We illustrate this by treating the discourse context as a conjoint set of constraints on the event variable – a representation that can in principle be modeled within Abstract Knowledge representations (Bobrow et al., 2007) or (segmented) discourse representation theory (Asher & Lascarides, 2003). For reasons of space and simplicity of exposition, we adopt this simple notion.

(12) $\{market(e) \wedge \tau(e) \subset yesterday \wedge yesterday \prec t_0\}$

(13) $\{meet(e) \wedge market(e') \wedge ag(e) = I \wedge th(e) = Peter \wedge loc(e) = loc(e') \wedge \rho(TT(e), t_0)\}$

The set of propositions in (13) represents the target sentence in (10). Both the market and the meeting are treated as an event whose share the same location. Agent and theme are self-explanatory in this case. However, the last element of the conjunct is interesting for us: ρ marks a relation variable.[13] This relation needs to be inherited from the context. For this to happen, the market in the context

[11] An observation also made by other approaches to temporal semantics, specifically TimeML (Saurí et al., 2006).

[12] Such verbs for example occur in Indonesian, where there is no overt finiteness marker on verbs. However, their syntactic context as well as their compatibility with certain finite auxiliars that are available in some syntactic constructions but not in others indicate that the Indonesian grammar possesses some sort of unmarked finiteness (Arka et al., 2013).

[13] We adopt this notion from Asher & Lascarides (2003).

and the market mentioned in the sentence have to be identical, because we then get the (trivially inferred) relation $yesterday \prec t_0$ as a possible reference for our relation variable. This process also correctly predicts that it is not specified at which instance of the market eventuality Peter is met. Thus, if there are multiple possible markets in the previous context, the variable relation could pick up any of them. However, this also means that if there is a future market mentioned in the context, it would be a possible antecedent for the relation in (13). This is not necessarily false and if we include the Question Q in (10), then the 'before' relation would constrain the possible values for ρ by virtue of the identity relation between the two instances of the event 'meet Peter' expressed in the question and the answer.

In this model, event identity is simply inferred from the syntax and semantics that is derivable from the surface structure.[14] Thus, the two market events in (12) and (13) are identical for the reason that they are expressed in a similar fashion overtly in the context and because the semantic constraints on them are not contradictory. For the present purposes we will accommodate this simple method of inferring event identity. Thus, zero-marked verbal predicates can inherit their tense features from identical antecedents in the discourse context. With this, we can define inheritance rules for the category of tense. In what follows, we have implemented entailments in terms of the $\rightarrow$ relation. We define contextual inferences, or contextual inheritance in terms of the $\circ$ relation (or compatibility relation).

(14) a. ctx($t_{TT} \prec t_0$) $\wedge$ MOOD 'indicative' $\circ$ TEMP-REF $\quad$ past : $t_{TT} \prec t_0$
b. ctx($t_{TT} \otimes t_0$) $\wedge$ MOOD 'indicative' $\circ$ TEMP-REF $\quad$ present : $t_{TT} \otimes t_0$
c. ctx($t_0 \prec t_{TT}$) $\wedge$ MOOD 'indicative' $\circ$ TEMP-REF $\quad$ future : $t_0 \prec t_{TT}$

The rule set in (14) states that, if we find a relation in the context, via inheritance, then the eventuality inherits that feature as its own tense feature. It is important to note that this does not mean that the zero-marked predicate expresses these semantics, but rather that the semantics are compatible with the expression, if it is warranted by the context.

If no suitable antecedent is available for the predicate, axiomatic inferences need to step in to resolve the temporal allocation of the eventuality. A simple example of such an axiom is the simplicity principle (Smith, 2006), which states:

(15) **Simplicity Principle of Interpretation**
Choose the interpretation that requires the least information added or inferred.

We are interested in inferring a temporal relation via this principle. In a language such as Indonesian, this can be difficult task. For example, in order to in-

[14] This in principle means we identify eventuality identities in the same fashion as is done with AKR semantics for question-answering systems (Bobrow et al., 2007). A commonality that is very much intended.

terpret (16), we first have to infer (via the simplicity principle) that the sentence is about a single house. In this case the VP 'build a house' is bounded (Krifka, 1998).

(16) John membangun rumah
John AV.build house
'John built a house.'

Since there is no overt aspectual marker, the simplest interpretation is a bounded one. A direct result of this is that the event cannot be about the present time, since the building event cannot possibly fit within what is perceived as *now* (Smith, 2006). Thus, the sentence can only be about the past or the future. However, the asymmetry between future and past tense makes past tense the simpler choice, since the future typically has a modal component. The result is that without any additional information we would infer that (16) is about a house building event in the past. Obviously, axiomatic interpretations of sentences are based on the semantics rather than the syntax and thus never express the primary meaning but rather an inferred secondary meaning.

3.3 Interim Summary

In this section we have seen a modeling of pragmatically inferred features, which, unsurprisingly, heavily depends on event identity. In cases, where contextual inferences fail to provide semantic features, axioms have to be stipulated that provide us with a suitable semantic interpretation. In this section we used the axioms assumed by Smith (2006).

Overall, we have devised a principled way of providing a syntax/semantics mapping for tense and aspect categories. Two main stages of semantic interpretation were illustrated: 1) primary meaning, i.e. a direct mapping from syntax to semantics; 2) pragmatic inferencing of semantic features through inheritance from earlier instances of the same situation in the context and the axiomatic modeling of pragmatic constraints.

4 Tense and Aspect and linguistic variation

In the previous section we proposed a basic system to describe different tense and aspect categories. In this section we look at more types of linguistic variation to illustrate how the system deals with more complex semantic phenomena across languages.

4.1 Parallel Alignment via INESS

For the exploration of linguistic variation and parallelism we rely on a mechanism that is provided by the INESS infrastructure: the cross-linguistic alignment system for parallel treebanks Rosén et al. (2009). This allows for phrase alignment

between LFG representations of parallel treebanks and, thus, provides an effective way of exploring cross-linguistic variation. The alignment tool allows us to mark alignments between cross-linguistically parallel phrases. The corresponding elements of the linguistic representations need to be syntactically compatible which means that there should be no contradictory constraints in the aligned f-structures. We carry this approach over to f-structure analysis to capture syntactic variation.

(17)
$$\left[\begin{array}{l} \text{OBJ} \left[\begin{array}{l} \text{PRED 'brev'} \\ \text{GEND} \quad \left[\text{FEM} -, \text{MASC} -, \text{NEUT} +\right] \\ \text{NTYPE} \quad \left[\begin{array}{l} \text{NSEM} \quad \left[\text{COMMON count}\right] \\ \text{NSYN common} \end{array}\right] \\ \text{SPEC} \quad \left[\text{DET} \left[\begin{array}{l} \text{PRED 'en'} \\ \text{DET-TYPE article} \end{array}\right]\right] \\ \text{CASE obl, DEF} -, \text{DEF-MORPH} -, \\ \text{NUM sg, PERS 3, REF} + \end{array}\right] \\ \qquad \left[\begin{array}{l} \text{OBJ} \left[\begin{array}{l} \text{PRED 'surat'} \\ \text{NTYPE} \quad \left[\begin{array}{l} \text{NSEM} \quad \left[\text{COMMON count}\right] \\ \text{NSYN common} \end{array}\right] \\ \text{PERS 3, TRANS letter} \end{array}\right] \end{array}\right] \end{array}\right]$$

Example (17) illustrates a set of parallel f-structures – NPs at c-structure – describing the object 'a letter' of our recurring example (2). Despite the clear difference in complexity between the two partial f-structure they can be aligned, since none of the features that occur in the two structures contradict one another. However, we aim for a deeper level of alignment between linguistic structures.

In our project we rely on ParGram grammar analyses compiled on the basis of the Dahl's (1985) testsuites. This parallel treebank is publicly available via the INESS treebanking infrastructure as ParTMA.[15] It includes data aligned from English, Georgian, German, Greek, Hungarian, Indonesian, Italian, Norwegian, Polish and Urdu.

4.2 Syntactic variation

There are various types of cross-linguistic variation beyond the purely morphosyntactic variation already discussed. By representing tense and aspect categories as mappings from syntax to semantics we get a clearer picture of cross-linguistic variation. For this purpose let us contrast our Norwegian dinner example with the corresponding sentence in German, as shown in (18). In the German (18b), the perfect is semantically parallel to the Norwegian past tense. In fact, in many instances the meaning of the German present perfect and the German past are indistinguishable

[15] http://clarino.uib.no/iness

(Musan, 2002). However, this does not follow straightforwardly from the morphosyntactic cues.

(18) [Q: When you visited Peter yesterday, what did he do after you had dinner? ANSWER:]

a. Peter skrev et brev
Peter write.Past a letter

b. Peter hat einen Brief geschrieben
Peter have.Pres a letter write.PPart

As can be seen, the two partial aligned f-structures that correspond to the German present perfect and the Norwegian past, respectively, contradict one another in two instances: the TENSE and the PERF features. Still, both of these f-structures can be mapped onto the same semantics, as shown below.[16]

(19)
$$\begin{bmatrix} \text{TNS-ASP} & \begin{bmatrix} \textbf{TENSE present} \\ \textbf{PERF +} \\ \text{MOOD indicative} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{TNS-ASP} & \begin{bmatrix} \textbf{TENSE past} \\ \textbf{PERF} - \\ \text{MOOD indicative} \end{bmatrix} \end{bmatrix}$$

(20)
$$\begin{bmatrix} \text{TNS-ASP} & \begin{bmatrix} \text{TENSE pres} \\ \text{PERF +} \\ \text{MOOD indicative} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{TNS-ASP} & \begin{bmatrix} \text{TENSE past} \\ \text{PERF} - \\ \text{MOOD indicative} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{TEMP-REF} & \text{`past'} : TT \prec ET \end{bmatrix}$$

Thus, the sentences are semantically alignable despite their syntactic difference, at least in the present context. This analysis begs the question of how to treat the third sentence that we have discussed in the same context.

(21) a. Peter akan menulis se.buah surat
Peter FUT AV.write one.CL letter
'Peter wrote a letter.'

b.
$$\begin{bmatrix} \text{TNS-ASP} & \begin{bmatrix} \text{TENSE future} \\ \text{MOOD indicative} \end{bmatrix} \end{bmatrix} \qquad \begin{bmatrix} \text{TEMP-REF} & \text{`future'} : \lambda t.t \prec TT \end{bmatrix}$$

The example in (21a) differs morphosyntactically and semantically from the corresponding German, Norwegian and English. Nonetheless, it is used to describe the same situation. In other words, all four variants can pick up the same event

[16] This effect does not mean that the two syntactic constructions are identical in the semantics they select. However, delving into the details of this topic goes beyond the scope of this paper. For an overview see Musan (2002).

variable, but they express different properties of the situation it occurs in. Thus, there is a parallel between the languages at a pragmatic level. (22) illustrates the desired meaning of our example (recall the temporal progression chart in Section 2.2).

(22) $\{letter(y) \wedge write(e) \wedge ag(e) = P \wedge theme(e) = y \wedge dinner(e') \wedge TT \prec t_0 \wedge \tau(e') \prec e \wedge e, e' \subset yesterday\}$

We have previously established that temporal relations are an integral part of the anaphoric nature of tenses, to the point that temporal relations in the discourse context can be picked up by temporal markers. The situation described by (22) is compatible with all of the three examples discussed so far. However, German and Norwegian overtly encode the relation $TT \prec t_0$, while Indonesian encodes the relation $\tau(e') \prec e'$.

In Kamp & Reyle (1993) another type of temporal relation is addressed: The relation of two topic times in subsequent sentences. The current topic time is related to the previous topic time by a presuppositional relation. It is, thus, important to note that the difference between sentences that express the future relation in (22) and sentences that express the absolute past relation in (22) may differ in the topic time they make available to the further discourse. This becomes more apparent if we look at the corresponding English sentences.

(23) a. John wrote a letter.
b. John was going to write a letter.

In (23a) the interpretation is such that the writing event took place, even if we squeeze in an additional event in between, as in *John wrote a letter. However, before that he took a shower.* On the other hand, in example (23b), it is not necessarily the case that the 'write a letter' event takes place and thus intuitively and by virtue of its grammatical form (non-finite) it does not seem to provide a topic time. Instead, the sentence implies that the topic time is still whatever *was* is picking up as temporal variable. There are various approaches to analyzing this, but the gist is, that there seems to be a modal operator, for example, a plan operator involved in these examples (Copley, 2009). However, from a purely temporal perspective, the difference falls out if we assume that the future marker in Indonesian and the *going to* construction in English are realizations of prospective aspect.

(24) a. $[\![past]\!] = \lambda P.\lambda t_{TT}.t_{TT} \prec t_0 \wedge P(t)$
b. $[\![prosp]\!] = \lambda P.\lambda t.\exists e[t \prec \tau(e) \wedge P(e)]$
c. $[\![prv]\!] = \lambda P.\lambda t.\exists e[t \supset \tau(e) \wedge P(e)]$

Under this assumption, there is a glaring difference between three languages with regard to how our dinner example is treated. While all three of them are still compatible with (22), only the presuppositional link inferred from the English past tense moves the topic time forward, while the overtly expressed prospective aspect

only moves the run-time of the event, but not the topic time forward. This corresponds nicely to the role of aspect to manage the relations between topic times in successive sentences that has been pointed out throughout the literature (Asher & Lascarides (2003); Comrie (1985); Kamp & Reyle (1993); Klein (1994); Smith (2006), just to name a few). The sentence *John wrote a letter.* would then be a combination of past tense and perfective aspect. The perfective aspect would shift the topic time to a point after dinner and simultaneously the run-time would be shifted to be contained within that topic time.

To summarize, our first observation was that syntactically contradictory representations can still be mapped onto the same meaning, although several complex semantic and pragmatic factors play a role. We have also seen that variation of both the syntax and the semantics leads to differences in terms of the interpretation of a sentence at the discourse level, although we only sketched a potential analysis of this type of variation. In the next section we focus on semantic variation.

4.3 Semantic variation

Semantic variation has already been addressed in this paper in terms of the distinction between deictic tenses, relative tenses and grammatical aspect. All of these have proven to be, in some instances, superficially similar but differing in the details. We illustrate this in terms of a semantic phenomenon that we have brought up before: sequence-of-tense.

The SOT phenomenon is a case of polysemy of morphological markers that introduce a semantic past. The effect is illustrated in the example below: The embedded predicate 'be-sick' can either be interpreted as simultaneous to the matrix event 'say' or in the past relative to it.

(25) Tom said that Karen was sick.
   a. Tom said: Karen is sick.
   b. Tom said: Karen was sick.

In the present framework we can devise a rule that captures these facts straightforwardly. For readability we have dissected the rule into various parts in (26). COMP refers to the fact that *E2* is embedded in a complement of *E1*.

(26) Let *E1* and *E2* be events constrained by syntax and semantics, then the following constraints have to hold:
   a. $COMP(E1, E2) \wedge PAST(E1) \wedge PAST(E2)$
   b. *E1* is a propositional attitude verb
   c. *E2* is a stative verb
   d. *E1* and *E2* are semantically or pragmatically past

The constraints in (26) expresses the minimal syntactic requirements, while b) through d) express the semantic/pragmatic requirements. If these requirements are met, the embedded semantic past is weakened to a relative tense picking up

the topic time of the matrix event and the embedded event expressing non-future. The non-future value can be resolved to either simultaneity or anteriority by pragmatic inferences. These semantics are also compatible with explicit restriction of the involved temporal variables via temporal modifiers.

However, we note at this point that the SOT phenomenon is not crosslinguistically robust (Grønn & von Stechow, 2010; Kusumoto, 1999, 2005). This means that the constraints devised in (26) as well as all the other rules are language specific. However, by describing tense and aspect categories in terms of correspondences between syntax and semantics, the substantial differences between the languages can be pin-pointed, rather than being led astray by superficial parallelism. For a more extensive discussion on this subject, see Zymla (2017).

5 Conclusion

In this paper we introduced a principled way of describing the interpretation of tense and aspect categories from syntax to semantics all the way to the pragmatic level. In order to achieve this, we employed a representation that displays linguistic categories as mappings from structure to meaning. The term structure covers morphological and syntactic information, while meaning is divided into primary meaning, i.e. directly inferable meaning and semantically constructed or pragmatically inferred secondary meaning.

We present an approach that interprets tense and aspect features as mappings from syntax to semantics, rather than as purely syntactic or semantic categories. Thus, a linguistic category can be understood as a set of rules that take as premises syntactic (and potentially semantic) features and generate (additional) semantic inferences akin to the resource-logical approaches to semantics used in LFG. A basic example of this is the explicit mapping from f-structure to semantic representation as in (27).

(27) a. $\left[\text{TNS-ASP} \left[\begin{array}{l}\text{TENSE past}\\ \text{MOOD indicative}\end{array}\right]\right] \quad \left[\text{TEMP-REF} \quad \text{`past'} : t \prec t_0\right]$

b. TENSE ‘past’ $\wedge$ MOOD ‘indicative’ $\rightarrow$ TEMP-REF ‘past’ : $t \prec t_0$

The analysis of linguistic categories as mappings from syntax to semantics allows for a straightforward comparison of the categories and their implementation as inference rules allows for various applications in NLP. Within LFG specifically, the linguistic representations can be directly mapped onto XLE transfer rules, rewrite rules that have already been used to map between syntax and semantics (Crouch, 2005; Crouch & King, 2006). Thus, the system presented here lays the foundation to generate new semantic resources for XLE grammars such as the ParGram grammars.

The syntax/semantics interface is fairly straightforward to implement and is supported by existing approaches to tense and aspect within LFG. To resolve prag-

matic inferences, we argued for a system that is heavily based around deriving identity functions between eventualities. Furthermore, we sketched possible axiomatic implementations of pragmatic information along the lines of Asher & Wada (1988) and based on the pragmatic account of temporal interpretation in Smith (2006).

Overall, the system that we advocate in this paper allows for the interpretation of covert processes in the inferential (pragmatic) and compositional (semantic) assembly of tense and aspect features across languages. This allows for a principled way of creating semantic resources for the analysis of tense and aspect within LFG, especially, with regard to the exploration of language parallelism and variation.

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