Perfective non-past in Modern Greek

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Abstract

This paper presents an analysis of the Greek tense/aspect system with a particular focus on the perfective non-past. It relies on the ParGram feature space for morphosyntactic analysis and the ParTMA semantic annotation scheme for semantic analysis. The whole analysis is computationally implemented, making use of the Xerox Linguistic Environment (XLE), the Glue Semantics Workbench (GSWB), and a new system for rewriting syntactic representations inspired by XLE's transfer system called LiGER.

1 Introduction

The present paper contributes to the large body of work providing computational resources for Lexical Functional Grammar building mainly on the international ParGram effort (Butt et al. 2002). More specifically, we present the continuation of the development of the Modern Greek (MG) ParGram grammar (Fiotaki and Tzortzi 2016) by adding a semantic interpretation component. This semantic resource is grounded in a description-by-analysis approach to Glue semantics and is implemented in the LiGER system (Linguistic Graph Expansion and Rewriting) that operates on top of the morphosyntactic analysis provided by the Xerox Linguistic Environment (XLE; Crouch et al. 2017).

In this paper, we present this system by focusing on the treatment of tense and aspect in the MG XLE grammar. The Greek tense/aspect system provides a complex picture that requires both syntactic and semantic analysis to be captured appropriately. Traditionally, the Greek verbal system is organized on the basis of tense (past/non-past) and aspect distinctions (perfective/imperfective; Holton et al. 1997 and Mozer 2009). The perfective non-past (henceforth PNP) plays a special role in this paradigm in that it is the only verb form that cannot occur freely in matrix clauses but requires certain licensors to be available. For this reason, it has been labeled 'dependent' in the literature (Holton et al. 1997). Consider the example in (1), where the PNP is ungrammatical. Unlike the imperfective non-past (INP) verb form, it needs to be licensed as shown here by virtue of the *na* (complementizer).

(1) O Christos *grap-sei/graf-ei ena gramma
DEF Chris write-*PNP.3SG/INP.3SG a letter
Chris is writing a letter.

(2) O Christos thimithik-e na grap-sei/graf-ei ena gramma
DEF Chris remember-3SG C write-PNP.3SG/INP.3SG a letter
Chris remembered to write/writing a letter.

The main goal of this work is to make a proposal for analyzing the PNP embedded in complement clauses introduced by *na* (Fiotaki and Lekakou 2018). The gist of

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this proposal is to distinguish between proper tenses and dependent tenses via the resources that they contribute to a Glue semantics derivation. While proper tenses introduce a tense operator and an evaluation time, dependent tenses (such as the PNP) pick up a temporal variable provided by some governing operator (similar to relative tenses). Crucially, the PNP never introduces an evaluation time itself, distinguishing it from other tense forms. This handling of resources is covered by semantic rewrite rules that produce Glue semantics meaning constructors, following description-by-analysis approaches (e.g., Andrews 2008). In the process, we refine the layered annotation proposed by the ParTMA annotation scheme (Zymla 2017, Zymla and Sulger 2017). More generally, this analysis follows ideas from Kusumoto (2005) and Giannakidou (2009) in terms of its semantic modeling.

The paper is organized as follows. §2 discusses the tense and aspect system in MG. In §3 the modeling of the semantics of tense and aspect is presented. §4 provides a detailed implementation of the morphosyntactic and semantic analysis of the examined verb type/PNP. We conclude and summarize our findings in §5.

2 Tense and aspect in Greek

In this section, we present the key observations of the MG tense/aspect system that provide the foundation for our syntactic and semantic analysis. We briefly describe the general paradigm but then quickly zoom in on the perfective non-past as the main point of interest.

2.1 The basic paradigm

In line with descriptive grammars of MG (Mackridge 1987, Holton et al. 1997, see also Mozer 2009), we take the Greek verbal system to be organized based on tense and aspect distinctions, namely past/non-past and perfective/imperfective.[1] The distinction between the perfective and the imperfective aspect appears morphologically in all grammatical verbal forms, whereas tense only appears as part of indicative clauses.

	perfective(PE)	imperfective(IP)
past(PAST)	e-grap-s-a	e-graf-a
non-past(NON_PAST)	grap-s-o	graf-o

Table 1: Modern Greek basic tense/aspect paradigm

In Table 1 the corresponding analysis of the Greek verb morphology is presented.[2] Let us first look at the lower left cell of the table: the imperfective non-past

[1]The PNP is historically related to the aorist subjunctive of Classical/Ancient Greek. Based on that, "traditionalists" maintain that MG has a morphological subjunctive. There are numerous reasons to reject this theory (see Tsangalidēs (1999) and (Sampanis 2012) for full discussion)

[2]For a more detailed discussion of Greek verbal morphosyntax see Mackridge (1987), Joseph

verb form is built of the stem *graf-* and the non-past tense marker (*-o*). In contrast, the imperfective past carries an unstressed (*e-*) before the stem *graf-* and the suffix (*-a*) to provide a past tense form. Similarly, perfective past carries an unstressed (*e-*) before the stem *graf-*and the tense marker (*-a*), but the latter is preceded by the marker for perfective aspect (*-s-*). Finally, the perfective non-past verb type is formed of the stem *graf-* followed by the perfective marker (*-s-*) and the non-past tense marker (*-o*).

2.2 The perfective non-past

The basic paradigm is straightforward; however, in this section, we show that the distribution of the perfective non-past indicates a more complex picture, where this particular form plays a special role that is not fully anticipated by the previously introduced 2x2 distinction.

2.2.1 The data

Our empirical investigation is based on data retrieved from the Hellenic National Corpus (henceforth HNC; http://hnc.ilsp.gr/), a balanced online monolingual corpus of MG texts developed by the Institute for Language and Speech Processing (ILSP). It currently contains approximately 50 million words and is constantly being updated (Hatzigeorgiu et al. 2000). There, we examined the occurrence of the sequence 'main verb + *na* + subordinate clause', extracting 7508 sentences. The general interpretation of the PNP in these sentences consists of future temporal reference and perfective viewpoint, i.e., a fully realized, episodic interpretation of the underlying eventuality (see also Fiotaki and Lekakou 2018).

The data suggests that the PNP only occurs in future shifted contexts. This will be crucial later, but first, we are going to examine its status as a 'dependent' verb form which is an important factor in modeling the syntax/semantics interface.

2.3 Tense and aspect of the PNP

The PNP has been called 'dependent' (Holton et al. 1997, Tsangalidēs 1999, Lekakou and Nilsen 2009, Giannakidou 2009), as, unlike the other finite verbal forms in MG, it cannot be used to form a full clause as shown in (1). It requires one of the following licensors: either the particle *na* which serves as a complementizer (see (2)), the future marker *tha* in (3), a optative/hortative marker (e.g. *as* shown in (4)), or other temporal connectives such as *prin* 'before' (Fiotaki and Lekakou 2018 and references cited therein). These are all operators that are able to shift forward the evaluation time of the verb they embed (directly or indirectly).

(3) Tha pei tin istoria ap'ekso
FUT say.PNP.3SG the story by heart
She will tell the story by heart.

and Smirniotopoulos (1993), Holton et al. (1997), and Ralli (2005) among others.

(4) As pei tin istoria ap'ekso
OPT say.PNP.3SG the story by heart
Let him tell the story by heart.

Example (5) illustrates the pattern 'main verb + embedding an INP', whereas the example (6) exemplifies the pattern we focus on in this paper: 'main verb + embedding a PNP'. In the first example, the event time is prior to the utterance time. The example (6) yields an event time that starts now and moves forward open-endedly, indicating a future shifted interpretation.

(5) Thimat-ai na leei tin istoria ap'ekso
remember-3SG C say.INP.3SG the story by heart
S/he remembers that she was telling the story by heart.

(6) Thimat-ai na pei tin istoria ap'ekso
remember-3SG C say.PNP.3SG the story by heart
S/he remembers to tell the story by heart.

As pointed out above and following Fiotaki and Lekakou (2018), the PNP is allowed in those embedded clauses in which the semantics of the main verb impose a future orientation of the embedded eventuality. Example (7) illustrates this point: the lexical semantics of the verb *iposxomai* 'promise' are compatible with a future-shifted complement as it is only possible to make a promise concerning the future. In comparison, verbs like *vlepo* 'see', *akuo* 'hear', *arxizo* 'start' disallow the PNP in the embedded clause as shown in (8)–(9). This is because they impose a simultaneous interpretation of their complement, or they force a habitual interpretation of the embedded eventuality. Thus, they are temporally or aspectually incompatible.

(7) Iposxethik-e na epistrep-sei ta xrhmata sintoma
Promise-3SG C return-PNP.3SG the money soon
S/he promised to return the money soon.

(8) Ton vlep-ei na *diasxi-sei/diasxiz-ei to potami
Him see-3SG C cross-*PNP/INP.3SG the river
S/he sees him crossing the river.

(9) Arxis-e na *pai-xei/paiz-ei podosfero eksi xronon
Start-3SG C play-*PNP/INP.3SG football six years
S/he started to play football when he was six years old .

In summary, we propose that the PNP introduces relative future temporal reference in embedded contexts. Although we cannot argue that the PNP itself constitutes a morphological subjunctive, it gets licensed by markers that are related to mood such as *na*.[3] In the next section, we focus on the temporal properties of the PNP and its interaction with the licensor *na*.

[3] Giannakidou (2009) mentions that *na* carries properties of both a subjunctive marker and a complementizer. Thus, the subjunctive flavor of the PNP is arguably a result of the interaction between it and *na*. An interesting result of this interaction is that PNP is preferred in non-veridical contexts.

3 Formal semantics for the PNP

Now that we have outlined the main assumptions of our analysis, we provide a formalization of mainly the semantic properties of the PNP (see Fiotaki and Tzortzi 2016 and section 4.1 for the basic morphosyntactic analysis and the revisions made for this paper). In this paper, we focus on the temporal properties of the PNP: first, its dependent nature with respect to temporal reference and, second, its obligatory future shift in relation to perfective aspect.

Following most research in the semantics of tense and aspect, we build our analysis on ideas from Reichenbach (1947) and its successors, as explained in the next section. Starting in section 3.2, the proposal is tailored towards integration in LFG. More concretely, we present a two-component semantic analysis that makes use of the ParTMA annotation scheme (Zymla and Sulger 2017, Zymla 2017). Section 3.2.1 describes semantic feature structures based on the ParTMA annotation scheme, which we call the ParTMA template. Mapping f-structures to these semantic features is the first part of our semantic analysis. Section 3.2.2 explains how this template can be interpreted, using a description-by-analysis approach to Glue semantics. The concrete implementation is presented in section 4.

3.1 The semantics of tense and aspect

Before proposing a compositional semantics for the PNP, let us first discuss the semantics on a more conceptual level. In general, temporal reference, i.e. the semantics we assume to be underlying morphosyntactic tense markers, is associated with locating a reference or topic time with respect to an evaluation time, usually the time of utterance or speech time (Reichenbach 1947).[4] The corresponding semantics are usually specified using time intervals (type *i*). However, pure interval semantics fall short when considering embedded contexts (for an elaborate discussion, see Kusumoto 1999). For this reason, we use situation semantics, i.e., entities of type s, to encode tense/aspect information, where situations are abstract entities with at least one property, e.g., world/time coordinates which are relevant for our analysis. Thus, we may sometimes call the reference time the reference situation.

Grammatical aspect, the semantic exponent of which we call viewpoint, encodes the (temporal) relation between the reference situation and the corresponding eventuality, where an eventuality is a situation describing a state or event and its participants (i.e., the information encoded in the predicate-argument structure). Viewpoint distinguishes between an external and an internal view of a given eventuality. More specifically, perfective viewpoint describes an eventuality as a whole, whereas imperfective viewpoint provides an internal viewpoint focusing on a specific part of the underlying eventuality (see, for example, Comrie (1976), Smith (2013)). In the next two sections, we focus on the semantic properties of the PNP.

[4]Reference time is the term used by Reichenbach, whereas the term topic time has been coined by Klein (1994), whose work is one of the works that started the *neo-Reichenbachian* tradition. We will stick to the former term for the sake of consistency.

3.1.1 The semantics of non-past temporal reference

Generally, temporal reference is encoded in terms of temporal constraints on situations using relations, such as the $\prec$-relation for precedence. Thus, the past tense is understood as a mechanism to temporally locate a situation before some evaluation time. On the most basic level, the non-past is the inverse: a mechanism that locates the reference situation in the present or the future. Thus, we need to get an understanding of these three basic tenses.

The semantics of past and future tense are often treated as temporal quantifiers. We employ the same approach, following Kusumoto (1999, 2005). These quantifiers simply ensure that the reference time is ordered appropriately with respect to the evaluation time, as exemplified for past temporal reference in (10-a). Conceptualizing the present tense is less straightforward. According to Abusch (1998), present tense is not necessarily constrained by some temporal relation, but rather denotes a temporal variable itself, which she calls n. This n usually but not necessarily corresponds to the evaluation or utterance situation in the temporal quantifiers for past and future temporal reference as well. Furthermore, tenses may remain uninterpretable in certain contexts. For example, Kusumoto (2005) assumes that, in complement clauses, a temporal quantifier is not obligatory. This means that such embedded tenses have two states: either they introduce a temporal quantifier or they are bound by a temporal quantifier higher up in the derivation. This explains the ambiguity that arises as part of the sequence-of-tense phenomenon (Abusch 1988, 1997, Grønn and von Stechow 2010)). In both cases, the tense of the embedded clause is interpreted relatively. Thus, tenses in complement clauses do generally not introduce an evaluation time.

What does this mean for MG non-past tense? First, we could assume that an ambiguity arises between a present interpretation and an interpretation of future temporal reference as initially suggested. Considering the discussion above, this would mean that there would be an ambiguity between two semantically different elements (a variable of type s and a quantifier of type $\langle st, st\rangle$, i.e., a modifier of sets of situations). However, this suggests challenges at the level of composition due to a type mismatch between present tense and future tense.

Giannakidou (2009) proposes a different interpretation of non-past: rather than denoting a disjunction of two different meanings, she suggests that, at least in the case of the PNP, non-past temporal reference denotes a time interval whose initial point is saturated by the evaluation time, and which extends infinitely into the future. Furthermore, she assumes that the non-past itself cannot introduce an evaluation time differentiating it from Kusumoto's tenses, thus making it dependent.

We adopt this view, but rather than treating non-past as a temporal variable in the same vein as Abusch's present tense and Giannakidou's non-past, we unify the treatment of all tenses to quantifiers to simplify the compositional process overall. This means tenses can occur in three forms. In (10-a), a typical temporal quantifier is shown. It is introduced together with an evaluation time, t^* of type s that is supposed to saturate its t λ-slot in matrix clauses (we ensure this later by matching the semantics with the corresponding Glue semantics resources). Example (10-b) illustrates the temporal quantifier associated with non-pastness based on Giannakidou's (2009) proposal: there exists some situation t' that starts at the evaluation time provided by the t λ-slot, and that extends infinitely into the future. This type of tense is defective in the sense that it can not provide an evaluation time, which distinguishes it from (10-a). As mentioned above, a tense marker might remain uninterpretable. This is, for example, the case when it is governed by another temporal operator of the same kind (Kusumoto 2005). In this case, such a variable is abstracted over to combine with an element higher up in the derivation. The abstraction step falls out naturally if we use a Glue semantics framework. This means that it does not need to be stipulated as a separate step in the semantic composition but surfaces in terms of different handling of the corresponding resources (cf. Kusumoto 2005). The next step is to encode these three different behaviors of tenses in a semantic feature structure suitable for a Glue-style composition. This is done in section 3.2.1. Before that, let us briefly discuss the semantics of viewpoint.

(10) a. **past:** $\lambda P_{<s,t>} \lambda t_s . \exists t'_s [t \prec t' \wedge P(t')]$
b. **non-past:** $\lambda P_{<s,t>} \lambda t_s . \exists t'_s . [t' = i(t, \infty) \wedge P(t')]$

3.1.2 The semantics of perfective viewpoint

Other than the non-past component of the perfective non-past, the aspectual component behaves more or less as expected in that it describes an episodic occurrence of an eventuality. As Giannakidou (2009) notes, when the perfective is applied to an eventuality that is a state, a meaning shift is induced that makes the underlying state eventive. Thus, we can generally assume that perfective viewpoint describes a situation in which the underlying eventuality is fully realized, i.e., the eventuality is fully contained within the reference time or situation provided by temporal reference (Comrie 1976, Bohnemeyer and Swift 2004). We model this as an existential quantifier over situations, which takes as arguments the corresponding eventuality and relates it to the reference time via a part-of relation. This is exemplified in (11-a). Conversely, imperfective viewpoint is encoded as a universal quantifier over situations following classical modal semantics for imperfective aspect and, in particular, progressive aspect, e.g., Dowty (1977). The restrictor of the quantifier encodes the flavor of imperfectivity, mainly distinguishing between a progressive and a habitual interpretation (Arregui et al. 2011, 2014).

(11) a. **perfective:** $\lambda P_{<s,t>} \lambda s_s . \exists s'_s [s' < s \wedge P(s')]$
b. **imperfective:** $\lambda P_{<s,t>} \lambda s_s . \forall s'_s . [MB_{prog/hab}(s', s) \rightarrow P(s')]$

Combining perfective aspect with present tense forces a future-shifted interpretation in many languages, e.g., Slavic languages and Urdu (De Wit 2016). This is compatible with the tenses we have specified above since the reference situation specified by non-past temporal reference extends into the future, ruling out a simultaneous interpretation of the corresponding eventuality.

3.2 A two-component semantic analysis for tense and aspect

Now that we have discussed the general properties of the tense/aspect semantics we presuppose for PNP, it is time to flesh out the formalization within a compositional framework. Concretely, we want to translate insights from the works cited above into a Glue semantics analysis. However, first, we explore the compositional process we envision more generally.

We have outlined above that tense applies on top of aspect and aspect applies to a given eventuality. This is formalized in a type-driven composition in Kratzer (1998). The order of composition proposed there is shown in Figure 1. The VP is modeled as a set of events that is bound by aspect (viewpoint following the present conventions). Viewpoint returns a set of intervals which, in turn, combines with semantic tense (temporal reference). The result is a set of time intervals.

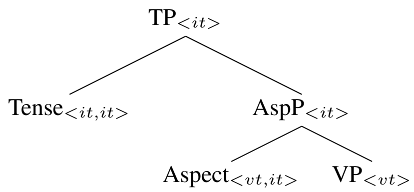

Figure 1: Compositional framework for tense and aspect

Since the present framework uses situations to model both tense and aspect (rather than time intervals and eventualities), the order of application needs to be restricted in another way than semantic typing. We solve this issue by using typing via Glue semantics which encodes both structural and type information at the same time based on the Curry-Howard isomorphism (Curry et al. 1958). The underlying structure for the composition is provided by the ParTMA annotation scheme.

3.2.1 The ParTMA annotation scheme

The parTMA annotation scheme provides an LFG-inspired annotation template that can be implemented in LFG's projection architecture as part of the semantic structure.[5] The ParTMA template contains three different components: i) a temporal reference component, ii) a viewpoint aspect component, and iii) a component for encoding lexical aspect. We focus on the first two components.

The first part of the two-component semantic analysis is a set of rules that generates a fully annotated ParTMA template from an f-structure input, i.e., the rules specify the syntax/semantics interface on a feature level (Zymla and Sulger 2017, Zymla 2017). As in the description-by-analysis tradition in Glue semantics, these rules match f-structure inputs and introduce additional information accordingly (Crouch and King (2006), Crouch (2005) for computational approaches and, e.g., Andrews et al. (2007), Andrews (2008) for theoretical discussion).

[5]The template can be structurally aligned with different morphosyntactic inputs, while the internal structure is preserved to cater to the specific needs of tense/aspect semantics.

$$\boxed{ID}\left[\begin{array}{ll} \text{LEX-ASP} & \left[...\right] \\ \text{TEMP-REF} & \left[\begin{array}{l} \textbf{T-REF} ::= \text{'PAST'} \mid \text{'PRESENT'} \mid \text{'FUTURE'} \mid \\ \text{'NON-PAST'} \mid \text{'NON-PRESENT'} \mid \text{'UNSPEC'} \\ \textbf{T-RESTR} ::= \text{'IMMEDIATE'} \mid \text{'RECENT'} \mid \text{'NON-RECENT'} \\ \textbf{EVAL} ::= \text{'FID'} \end{array}\right] \\ \text{VIEWPOINT} & \left[\begin{array}{l} \textbf{ASPECT} ::= \text{'PERFECTIVE'} \mid \text{'IMPERFECTIVE'} \\ \textbf{RESTR} ::= \text{'PROGRESSIVE'} \mid \text{'HABITUAL'} \mid \text{'ONGOING'} \mid \\ \text{'TERMINATED'} \mid \text{'CULMINATED'} \end{array}\right] \end{array}\right]$$

Figure 2: ParTMA eventuality template

Figure 2 presents the relevant part of the ParTMA template. As shown there, temporal reference specifies not only the temporal relation but also the evaluation time. As discussed in section 3.1.1, this is crucial for distinguishing relative tenses from absolute tenses and also plays a role in semantic phenomena not discussed in this paper, such as sequence-of-tense and double-access readings.

Mapping f-structure features onto these semantic features is relatively straightforward. In the next section, we explain how to use description-by-analysis methods to interpret the ParTMA annotation scheme while preserving the more hierarchical structure proposed in Figure 1 at the beginning of the section.

3.2.2 Semantic interpretation of the ParTMA annotation scheme

The ParTMA annotation template is interpreted via a description-by-analysis Glue semantics component that assigns meaning constructors to the feature structures introduced in the previous section. The goal is to make use of the compositional hierarchy proposed in section 3.2 to derive the semantics of tense and aspect.

Traditionally, in LFG, tense and aspect are treated as modifiers of a clause that appear as functional features in the f-structure (Butt et al. 1999). This is also the treatment generally proposed in description-by-analysis analyses (e.g., Andrews 2008). Haug (2008) proposes a different approach, distinguishing between modification of eventuality time and reference time, following Klein (1994). The architecture presented in this paper is similar but more fine-grained.

As shown in Figure 3 and Figure 4, the eventuality is specified at the level of `LEX-ASP` and is then related to the reference situation by viewpoint and finally to the situation of evaluation by temporal reference. Instead of encoding the hierarchy in terms of different semantic types as shown in section 3.2, we use linear logic to guide the composition. Together with the semantics specified in section 3.1.1 and 3.1.2 we can thus produce meaning constructors allowing for a Glue semantics calculation of the tree in Figure 3. Our goal of following the composition order in Figure 1 is thus achieved: We have mapped the relatively flat structure of the

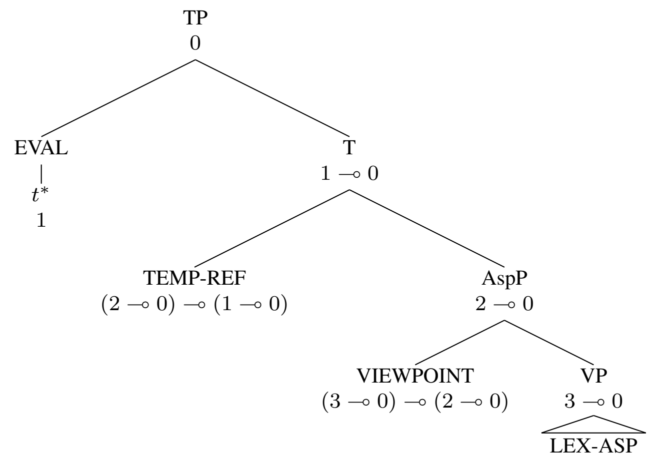

Figure 3: Order of composition of the ParTMA features

$$
{}_{0}\begin{bmatrix} \text{TEMP-REF} & {}_{2}\begin{bmatrix} \ldots & \\ \text{EVAL} & {}_{1}\big[\ldots\big] \end{bmatrix} \\ \text{VIEWPOINT} & {}_{3}\big[\ldots\big] \\ \text{LEX-ASP} & {}_{4}\big[\ldots\big] \end{bmatrix}
$$

Figure 4: Indexation of the ParTMA template

ParTMA template onto a tree structure for the sake of the underlying composition.

This has another reason in addition to following the proposal made by Kratzer (1998). This reason is technical: since the logic that guides the composition is inherently commutative (Asudeh 2012), glue approaches to compositional semantics suffer from abundant spurious ambiguity, in particular, in the computational domain. By encoding structural constraints within the Glue side of meaning constructors, commutativity is generally preserved while constraining the resulting combinatory explosion in areas where it is not required.

However, one of the disadvantages of this system is that features can not remain unspecified, since it would break the chain of composition that percolates all semantic information to the top node of the tree. Thus, the semantic interpretation component of the ParTMA template interprets unspecified features as identity functions that simply pass semantic information up the tree. This is not a very costly processing step. The benefits of avoiding combinatory explosion outweigh the cost of this additional step.

4 Implementation

In this section, we illustrate parts of the implementation of the analysis described above within the XLE and the LiGER system for modifying XLE's syntactic output. First, we will briefly recap the morphosyntactic modeling of the PNP within the XLE grammar and the resulting f-structures in the next section, then we explain the implementation of the two-component semantic analysis in section 4.2.

4.1 Morphosyntax in the Greek XLE grammar

The current version of the fragment of Modern Greek presents progress on the MG XLE grammar (Fiotaki and Tzortzi 2016), in particular with respect to the treatment of tense and aspect (TA) by adopting the ParGram TAM (Tense/Aspect/-Mood) scheme (Butt et al. 2002). As discussed in section 2.1, in MG there are four verb forms that are annotated for tense and aspect. The annotation scheme used is exemplified in the INP lexical entry *paizei* 'plays' presented in Figure 5.

```
paizei V * @(OPT-TRANS PAIZW)
            (^ TNS-ASP TENSE)=NON_PAST
            (^ TNS-ASP ASPECT)=IP
            (^ TNS-ASP MOOD)= indicative
           @(TRANSL play)
           @(PERS 3)
           @(NUM SG).
```

Figure 5: Lexical entry: *paizei*

A lexical entry encoding the PNP for the verb *paizw* 'play' is given in Figure 6. It is annotated for the tense and aspect features, but also for its inability to occur on its own in matrix contexts, with the feature `DEPENDENT` and the value `YES`. This feature is an artifact. It was implemented based on the descriptive analysis discussed in section 2.1 and is used as a stipulation to avoid over-generation of the syntactic component with respect to the PNP. However, it is not required for the semantic analysis. More concretely, the semantic annotation of the PNP proposed in this paper rules out the same parses in a syntactic grammar that does not contain the feature `DEPENDENT` (see section 4.3).

```
paiksei V *  @(OPT-TRANS PAIZW)
              (^ TNS-ASP TENSE)=NON_PAST
              (^ TNS-ASP ASPECT)=PE
              (^ TNS-ASP MOOD)= indicative
             @(DEPENDENT YES)
             @(TRANSL play)
             @(PERS 3)
             @(NUM SG).
```

Figure 6: Lexical entry: *paiksei*

A slightly simplified sample f-structure analysis is given in Figure 7 for the sentence ‘I don’t think that he will win the race.’ The main verb in the presented example is the verb *pistevo* ‘believe’. The particle *na* is treated as a complementizer (see Roussou (2000) among others) and it is encoded in the c-structure and surfaces in the f-structure by virtue of the `COMP-FORM` feature with the value *na*. The tense/aspect information for the PNP is given under the attribute `TNS-ASP`.

$$
1\left[\begin{array}{ll}
\multicolumn{2}{l}{\text{PRED `}\textsc{pistevo}\text{<[1-SUBJ:PRO],[5:}\textsc{kerdisei}\text{]>'}} \\
\text{SUBJ} & \left[\text{PRED `PRO'}\right] \\
\text{COMP} & 5\left[\begin{array}{ll}
\multicolumn{2}{l}{\text{PRED `}\textsc{kerdizo}\text{<[5-SUBJ:PRO],[10:}\textsc{agonas}\text{]>}} \\
\text{SUBJ} & \left[\text{PRED `PRO'}\right] \\
\text{OBJ} & \left[\text{PRED `}\textsc{agonas}\text{'}\right] \\
\text{TNS-ASP} & \left[\begin{array}{l}\textbf{ASPECT PE}, \textbf{TENSE NON\_PAST}, \\ \text{MOOD } \textsc{indicative}\end{array}\right] \\
\multicolumn{2}{l}{\textbf{COMP-FORM } \textsc{na}, \textbf{ DEPENDENT YES}, \ldots}
\end{array}\right] \\
\text{TNS-ASP} & \left[\begin{array}{l}\textbf{ASPECT IP}, \textbf{TENSE NON\_PAST}, \\ \text{MOOD } \textsc{indicative}\end{array}\right] \\
\multicolumn{2}{l}{\text{CLAUSE-TYPE } \textsc{decl}\text{, NE\_FORM } \textsc{de}, \ldots}
\end{array}\right]
$$

Figure 7: f-structure: *I don’t think he will win the race.*

4.2 Implementation of the semantics

The two-component semantic analysis approach for handling tense/aspect in MG presented in 3.2.2 is implemented in a system called LiGER (Linguistic Graph Expansion and Rewriting).[6] The system is inspired by the XLE’s transfer system, which has proven to be quite versatile. For example, it has been used to implement a semantic parser (Crouch 2005, Crouch and King 2006) and a reasoning engine (Bobrow et al. 2007), beyond its initially envisioned use as a system for machine translation (Frank 1999).[7] It is grounded in the wish to make linguistic annotation resources more cross-compatible. More concretely, the goal is to use a uniform graph format for linguistic annotations as inspired by Ide and Bunt (2010) and, more generally, the efforts concerned with interoperable annotation schemes.

The general architecture of the system presented in this paper is illustrated in Figure 8. The XLE is used to produce a morpho-syntactically annotated treebank (see section 4.1). The resulting parses are then accessed by the LiGER system and rewritten one by one, adding a semantic graph structure and the meaning constructors for the semantic derivation as leaves of this structure. These are given to the

[6] https://github.com/Mmaz1988/abstract-syntax-annotator-web

[7] Unfortunately, the transfer system is not supported by newer versions of the XLE and, thus, by more recent efforts concerning the XLE.

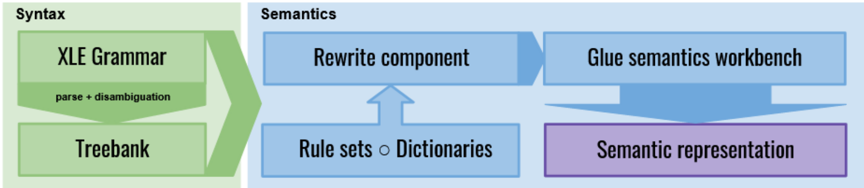

Figure 8: Annotation pipeline for DBA semantics

Glue Semantics Workbench (GSWB) to calculate the Glue derivation and produce the final semantic representation (Meßmer and Zymla 2018).[8] The GSWB provides a framework for computational work in Glue semantics, offering a modular structure to work with different meaning languages and linear logic provers.[9]

4.3 Description-by-analysis in LiGER

As described in section 3.2, we consider two different sets of rules for deriving the semantic analysis. One set establishes the semantic structure provided by the ParTMA template and the second set of rules "interprets" the semantic structure to produce the corresponding meaning constructors. We, therefore, call the first set semantic construction rules and the second set semantic interpretation rules.

In LiGER, these are encoded in terms of an ordered set of rules with rewriting capabilities. As discussed in section 3.2.2, this is because all features are required to be specified even if their value is unspecified The special role of features with the value `unspecified` is to introduce identity functions that raise semantic resources within the derivation tree in Figure 3. This is similar to manager resources used in, e.g., Haug (2008), Asudeh (2004).

Furthermore, as shown in Zymla and Sulger (2017), certain kinds of meaning shifts can be encoded in terms of layered interpretations of the respective features. This layering is encoded within the rewrite rules. Where applicable, first, the default interpretation rule applies, and if the semantics require it, the default value is rewritten into the appropriate value.

4.4 Semantic construction

Rules consist of a left-hand side and a right-hand side separated by an arrow ('==>'). The syntax that is used to specify the two sides is inspired by the INESS query language (Rosén et al. 2012). Hash signs in combination with alphanumeric values serve as variables over f-structure, or more generally, graph nodes (the f-structure is in principle a directed (acyclic) graph). Nodes may be connected via

[8] https://github.com/Mmaz1988/GlueSemWorkbench_v2

[9] See, for example, XLE+Glue which allows meaning constructors to be defined directly within XLE's output representations, while working with different meaning languages (Dalrymple et al. 2020).

relations or labeled edges from a graph perspective. The right-hand side of a rule expands a matching graph with the nodes and edges it specifies. Thus, the rule in (12) initializes the feature `T-REF` (for temporal reference) as `undefined` for all `TNS-ASP` nodes, ensuring that all such nodes are interpreted. The ParTMA template is, thus, constructed under the `SEM` attribute, which is mapped onto an unused variable (i.e., a variable that does not occur on the left-hand side). The `SEM` relation can be understood as a mapping to a semantic structure.

(12)
```
#a TNS-ASP #b
==> #a SEM #c & #c TEMP-REF #d &
#d T-REF 'undefined'.
```

Rule (13) is crucial for interpreting the PNP. As shown there, this rule does not introduce an evaluation time. Compare this to rule (14) for the INP in (14) which does so.[10] Note that both of these rules rewrite the initially provided default value. The differences between interpreting the PNP and the INP are subtle since both need to check for potential governing operators. The difference is that the INP may align its evaluation time with a governing operator, whereas the PNP is required do so, since it does not itself have the potential to be saturated by an external evaluation time, i.e., the speech time.

(13)
```
#a TNS-ASP #b TENSE 'NON_PAST' & #b ASPECT 'PE' &
#a SEM #c TEMP-REF #d & #d T-REF 'undefined'
==>#d T-REF 'non-past'.
```

(14)
```
#a TNS-ASP #b TENSE 'NON_PAST' & #b ASPECT 'IP' &
#a SEM #c TEMP-REF #d & #d T-REF 'undefined'
==>#d T-REF 'non-past' & #d EVAL #e & #e CHECK '-'.
```

The rule in (15) serves to account for the lacking evaluation time in the PNP rule. It is one example of a rule that searches for an appropriate licensor of the PNP, which can provide an evaluation time. In other words, the temporal reference of the PNP (`non-past`) is only fully specified in the context of a proper licensor (here a complementizer as indicated by the `COMP` relation. The licensor is searched for via inside-out functional application as indicated by the ^-symbol.)[11] The necessity of an evaluation time to interpret temporal reference is shown later in rule (18-a). From a resource perspective, the evaluation time is co-described with the temporal variable of the matrix verb, leading to the desired relative interpretation.[12] Con-

[10]The `CHECK` feature is used to distinguish between bound and unbound occurrences of tense operators. The default value is `'-'` indicating that the evaluation time is provided externally (i.e., it corresponds to the utterance time) rather than by some other element in the computation such as, for example, a complementizer. This value is rewritten if such a potential binder is found.

[11]LiGER allows to check for the typical LFG relations *(inside-out) functional application* and *(inside-out) functional uncertainty* using the same symbols as the XLE: fa `!`, iofa `^`, and `*` for functional uncertainty respectively.

[12]The rule shown here is particular to a specific licensor for the PNP. However, the approach can be easily extended to others in a straightforward manner, either by simply introducing additional

versely, the PNP does not receive a semantic interpretation in matrix clauses since no evaluation time is specified for it there.

(15)
```
#a TEMP-REF # b T-REF 'non-past' &
#a VIEWPOINT #c ASPECT 'prv' &
#a ^(SEM>XCOMP) #d & #d !(SEM>TEMP-REF) #e EVAL #f
==> #a EVAL #e.
```

The rule for interpreting aspect shown in (16) picks up this s-structure node to add the semantic features for VIEWPOINT which encodes the semantic information of the markers for grammatical aspect (ASPECT in f-structure).

(16)
```
#a TNS-ASP #b ASPECT 'pe' & #a SEM #c
==> #c VIEWPOINT #d &
#d ASPECT 'prv' & #d A-RESTR 'partOf'.
```

In sum, the semantic construction rules produce a feature structure that reflects the semantic properties of tense and aspect. In the case of the PNP, the perfective aspect behaves as expected in that it follows the common analyses that postulate that the eventuality time is included in the reference time (here encoded as a part-of relation). The temporal dimension of the PNP provides a deficient instance of temporal reference that does not itself introduce an evaluation time. Following the discussion of the semantic interpretation rules, this ensures that the PNP can not occur in matrix clauses since this would lead to a resource deficit. This will become more clear in the context of the semantic interpretation rules discussed next.

4.5 Semantic construction

Let us first take a look at the fairly uncontroversial rules for interpreting viewpoint in (17). There, we present the rules that apply in the case of perfective aspect as encoded by the rules described above in (16). In other words, the following rules take as input the output of the rules presented before.

The quantifier over situations contributed by perfective aspect (see section 3.1.2) is decomposed into its restrictor and scope similar to the treatment of NP quantifiers (Dalrymple et al. 1999). Correspondingly, the rule in (17-a) introduces a VAR node and a RESTR node for this aspectual quantifier. The next rule uses these additional nodes to establish its restrictor, namely, the part-of relation. The final rule in (17-c) picks up the restrictor in typical Glue semantics fashion to provide a quantifier over situations that picks up the eventuality description and raises it to the level of temporal interpretation.

(17) a.
```
#a SEM #b VIEWPOINT #c
==> #c VAR #d & #c RESTR #e & #c ASP-RESTR #f.
```

rules that follow the same schema or by introducing the evaluation time separately and then linking it to the temporal reference annotation of the embedded eventuality, which would arguably be more in line with Giannakidou's (2009) proposal.

b.
```
#a SEM #b VIEWPOINT #c A-RESTR 'bounded' &
#c VAR #d & #c RESTR #e & #c ASP-RESTR' #f
==> #f GLUE [/s_s.[/t_s.partOf(t,s)]] :
(#d -o (#e -o #c)).
```
c.
```
#a SEM #b VIEWPOINT #c ASPECT 'prv' &
#c VAR #d & #c RESTR #e & #b TEMP-REF #f
==> #c GLUE
[/M_<s,<s,t».[/p_<s,t>.[/s_s.Ez_s[M(s)(z) & p(z)]]]] :
((#d -o (#e -o #c)) -o ((#c -o #b) -o (#f -o #b))).
```

At the level of temporal reference, the procedure is conceptually the same. The restrictor of the temporal quantifier is defined in (18-a). The rule in (18-b) checks whether temporal reference needs to be interpreted by checking for a feature other than `undefined`. In that case, a quantifier is introduced that carries an open situation slot that is saturated by whatever specifies the evaluation time of that quantifier, i.e., the speech time or some governing element, as is the case with the PNP.

(18) a.
```
#a SEM #b TEMP-REF #c T-REF 'non-past' &
#c EVAL #d
==> #c T-REF' #e &
#e GLUE [/t_s.[/t2_s.equals(t,i(t2,∞))]] :
(#c -o (#d -o #c)).
```
b.
```
#a SEM #b TEMP-REF #c T-REF %a &
%a != 'undefined' & #c EVAL #d
==> #c GLUE
[/T_<s,<s,t».[/P_<s,t>.[/s_s.Er_s[T(r)(s) & P(r)]]]] :
((#c -o (#d -o #c)) -o ((#c -o #b) -o (#d -o #b))).
```

Ultimately, the rules illustrated above produce the four meaning constructors presented in (19): two for viewpoint and two for temporal reference. Furthermore, the system provides a semantics for the VP consisting of information about the verb, its arguments, and inner aspect. These are subsumed in the VP placeholder. As shown in Figure 9, the combination of these meaning constructors is straightforward and mimics the compositional process described in section 3.2.2.

In the present pipeline, the derivation is conducted by the GSWB based on all the `GLUE` nodes introduced by the semantic interpretation rules discussed above. As described throughout this paper, the node modified for temporal reference still requires an evaluation time, here represented by the resource corresponding to index 1 (see Figure 9). The grammaticality of the PNP hinges on the fact whether this value is instantiated by rules like the one in (15). Thus, as already stated, the ungrammaticality of the PNP in matrix clauses is a simple case of a lacking resource.

(19) **VIEWPOINT:** $\lambda s_s.\lambda t_s.t <_p s : 4 \multimap (5 \multimap 3)$

$\lambda M_{<s,st>}.\lambda p_{st}.\lambda s_s.\exists z_s[M(s)(z) \wedge p(z)] :$
$(4 \multimap (5 \multimap 3)) \multimap (3 \multimap 0) \multimap (2 \multimap 0)$

$$
\begin{array}{ll}
\textbf{TEMP-REF:} & \lambda t_s.\lambda t''_s.t = i(t'', \infty) : 6 \multimap (7 \multimap 2) \\
& \lambda T_{<s,st>}.\lambda p_{st}.\lambda s_s.\exists r_s[M(r)(s) \wedge p(r)] : \\
& (6 \multimap (7 \multimap 2)) \multimap (2 \multimap 0) \multimap (1 \multimap 0) \\
\textbf{VP:} & \lambda s.VP(s) : 3 \multimap 0
\end{array}
$$

$$
\dfrac{\dfrac{3 \multimap 0 \quad \dfrac{(4 \multimap (5 \multimap 3)) \multimap (3 \multimap 0) \multimap (2 \multimap 0) \quad 4 \multimap (5 \multimap 3)}{(3 \multimap 0) \multimap (2 \multimap 0)}}{(2 \multimap 0)} \quad \dfrac{(6 \multimap (7 \multimap 2)) \multimap (2 \multimap 0) \multimap (1 \multimap 0) \quad 6 \multimap (7 \multimap 2)}{(2 \multimap 0) \multimap (1 \multimap 0)}}{(1 \multimap 0)}
$$

Figure 9: Partial derivation: Temporal reference and viewpoint of the PNP

This section has illustrated some capabilities of the LiGER system by illustrating some of the rules written for MG. As shown here, the core capability is based on basic graph pattern matching and checking for equations between features. However, it also supports further capabilities, such as checking for long-distance dependencies by using a mechanism inspired by (inside-out) functional uncertainty, which will be explored in future work.

5 Summary

We have presented work on the Modern Greek ParGram grammar developed in the XLE and a refinement of the ParTMA annotation scheme. Concretely, we added a semantic analysis to the grammar that captures the particular properties of the perfective non-past, a dependent verb form. We attributed this dependency to missing information in the semantics of temporal reference, following an analysis by Giannakidou (2009) and the semantic analysis of tense in Kusumoto (1999, 2005).

These ideas have been compiled into a Glue semantics treatment of tense and aspect providing insights into dealing with the resources contributed by different tense markers. More concretely, we have provided a two-component analysis that makes use of the ParTMA annotation scheme as a separate structure that serves as input to an interpretation procedure grounded in description-by-analysis approaches to Glue semantics (Andrews 2008).

On a more general level, the present paper has shown a new way of implementing description-by-analysis Glue semantics: the LiGER system, which is a new open-source resource for adding and rewriting annotations such as XLE's syntactic output. Combining this system with the XLE and the GSWB, we provide an alternative to XLE+Glue (Dalrymple et al. 2020), which specifically aims at covering the areas of Glue semantics research that are left open by this resource.

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