

Tense and Aspect: A Mereological Approach *

Enrico Franconi, Alessandra Giorgi[†] and Fabio Pianesi

IRST

I-38050 Povo TN, Italy

e-mail: {franconi, giorgi, pianesi}@irst.it

Abstract

The purpose of this work is to provide a framework to address tense and aspect (*Aktionsarten*) phenomena in an unified way, mainly focusing on semantic representation. To achieve this goal we propose that: a) verbal morphology plays a crucial role in specifying the temporal meaning of a sentence and b) that morphosyntactic rules hold cross linguistically. For the purposes of semantic representation, we model the domain of events within an non-extensional mereological framework. This allows for a proper representation of perfective and imperfective events and of habituals, by means of plural quantifiers ranging on collections of events. With respect to tenses, we consider the present and the present perfect in Germanic and Romance, showing how different behaviours can be reduced to morphosyntactic differences. The relevance of this work for NLP lies in the conciseness of the semantic representations and in the compactness and generality of the linguistic knowledge bases (grammars, lexicons, semantic rules) allowed by the framework discussed.

1 Introduction

In this work we address the task of providing a unified account to phenomena in the domain of tense and aspect (*Aktionsarten*). Our strategy will be the following: verbal morphology plays a crucial role, specifying the basic units upon which the temporal and aspectual meaning of the sentence is built. Furthermore, syntax combines these morphemes in a maximally regular way, i.e. the syntactic structure of the verbal system is almost invariant across the languages we consider here. Although we won't be able to give much detail about syntax and syntactic processing (but, see

[Giorgi and Pianesi, 1991; Giorgi and Pianesi, 1992a; Giorgi and Pianesi, 1992b]), a central feature is the integration of levels of description that have been traditionally set apart, i.e. syntax and morphosyntax. Here, our attention will focus on semantic descriptions and on the domain for semantic interpretation, with a particular emphasis on the role of the *part-of* relation.

In Section 2, a number of phenomena will be considered in Romance and Germanic languages, which induce contrasting grouping. We will analyse the *present* tense, often considered to be one of the less controversial ones. The kind of solutions we will propose, will also play a role in explaining the behaviour of the *present perfect* and can be shown to be generalizable to other tenses. In Section 3 we will consider the question of how to structure the domains for tense and aspect interpretation and we will introduce an *non-extensional mereological* framework as the basis of our account. This theory has been independently developed and applied within the framework of terminological logic, where a calculus has been provided [Allgayer and Franconi, 1992a; Allgayer and Franconi, 1992b; Franconi, 1993]. In Section 4, we extend the mereological theory to the event domain, discussing the examples of Section 2. Finally, in Section 5 we will briefly discuss how these representations can be computed.

2 The present and the present perfect

In previous work [Giorgi and Pianesi, 1991; Giorgi and Pianesi, 1992a; Giorgi and Pianesi, 1992b] we adopted a neo-Reichenbachian framework [Reichenbach, 1947] to account for the temporal systems of several Romance and Germanic languages. Our aim was to connect temporal semantics to morphosyntax, under the assumption that it is the verbal morphology, which, once associated to a peculiar verb (i.e. combined with a specific *Aktionsart*) determines the array of the possible interpretations.

We start with the present tense. In this respect, English differs from all other Germanic and Romance languages; Italian, on the contrary, can be taken as a representative of the latter (examples are given in English and in Italian). With accomplishment and activity predicates, English does not allow the 'continuous' (or 'imperfective') reading, contrasting with all the other languages (we do not consider, here, the progressive present tense, which in English con-

* The present work has been partially supported by the Italian National Research Council (CNR), project "Sistemi Informatici e Calcolo Parallelo", and by the Irist Maia project. We gratefully acknowledge the comments by Achille Varzi on an earlier version of this paper. All the remaining errors are, of course, our own.

[†] Current address: Department. of Modern Philology, University of Catania, Italy.

veys imperfective meaning, and the so called *reportive* present):¹

- (1) a. John eats a chicken
b. John runs
- (2) a. Gianni mangia un pollo
b. Gianni corre

(1)a cannot mean that "John is presently involved in an act of eating a chicken" and analogously (1)b does not mean that "John is presently involved in an act of running". On the contrary, these readings are available in the other languages.

The possibility of imperfective readings, disappears, even in Italian, with achievement predicates:

- (3) John finds a book
- (4) Gianni trova un libro

The only available interpretation is, in fact, the reportive one.

Both in English and in Italian, present tense can express *habituality*, for instance *John eats chickens* can mean that John is a chicken-eater and *John runs* that John is a runner.

Finally, the present tense in *all* Germanic and Romance languages does not allow for perfective readings, i.e. it is not possible for a sentence like (1)a. or b. to mean that at the speech time an act of eating an apple was performed by the subject.

Under a *perfective reading*, an event is seen as a single, complete whole [Smith, 1991]. This does not mean that it may not have subparts; rather, if subparts exist, they are not used for referential purposes. When an accomplishment predicate is interpreted perfectly, the realization of the *telos* (*culmination*) is implied; e.g., the sentence *John ate an apple* entails that the eating event went on until the apple was finished. On the other hand, *imperfective readings* do not imply the existence of the whole and/or of the culmination, permitting access to the substructure of events.

In [Giorgi and Pianesi, 1992b], the characteristic behaviour of the English present tense with accomplishment and activity predicates was connected with the peculiar status of the English verbal stem (in X-bar theoretic terms, it is an X^0 , i.e. a full word, whereas it is an X^{-1} , i.e. a bound morpheme, in the other languages; cf [Roberts, 1991]). On the semantic side, this entails that the English verbal stem (of eventive predicate) is always associated with a perfective event.

Consider now the present perfect. In this case, Romance and Germanic languages are grouped differently, i.e. English is not isolated but patterns with Mainland Scandinavian (i.e. Danish, Swedish and Norwegian). In the other group we find Italian and Romance, but also Icelandic, German and Dutch. Again, Italian and English are taken as representatives. The contrast we are interested in concerns the possibility of adding a specific temporal reference to the present perfect:

- (5) a. John left at four

¹ Here, we adopt the so called Aristotele-Dowty-Vendler classification of aspectuality; see [Dowty, 1979]. Furthermore, we do not consider the present tense of statives.

- b. John has left
 - c. *John has left at four
- (6) Gianni e' partito alle quattro

As Comrie in [Comrie, 1976; Comrie, 1985] shows, a *locating* time adverbial like *at four* is incompatible with a verbal form like *has left*, but not with the corresponding Italian form *e' partito*; furthermore, this phenomenon does not generalise to other kind of temporal adverbials (e.g. *recently*) whose reference may include the speech time.

The role of morphemes is once more crucial in the explanation of these facts [Giorgi and Pianesi, 1992a; Giorgi and Pianesi, 1992b]. The English and Mainland Scandinavian morphemes that combine with the verb to give present tense forms (i.e. *-s*) have a temporal meaning ($S=R$, in Reichenbachian terms; these morphemes are said to be of category AGR/T) that the corresponding morphemes of the other languages lack (their category is AGR). In Section 4 we will use this asymmetry to explain the different behaviour of the present perfect.

3 Event domains

In order to account for the phenomena discussed in the previous section, we need a formalism to make statements about collections of events and their parts. According to a recent influential proposal [Bach, 1986], events form an atomic boolean algebra under an (individual) part-of relation (with the relative join operation). A subset of the atoms (the set of *processes*) is structured by another, different relation, i.e. the process part-of relation (with the relative join), forming a join semi-lattice. The whole system is connected to this subsystem by an homomorphism mapping events into processes. Bach also introduces a temporal part-of (∞) and an overlapping (O) relation, the former being a strict partial order (i.e. transitive, irreflexive and symmetric) and the latter reflexive and symmetric (cf. [Kamp, 1979]).

For the purposes of this work, we will borrow from Bach the temporal part-of and the overlapping relations and will use a mereological [Simons, 1987] approach, independently developed for the objectual domain [Allgayer and Franconi, 1992a; Franconi, 1993]. The features of this approach relevant to our work are: a) the possibility of defining plural operators and quantifiers and b) the fact that the theory has already been applied within the framework of terminological logics [Allgayer and Franconi, 1992a; Franconi, 1993], where a calculus has been proposed. The importance of terminological logics to represent the logical form of a sentence has been often emphasised (e.g., see [Lavelli *et al.*, 1992]).

3.1 A Mereological Approach

We consider, now, *collective entities*, or *collections* [Sowa, 1991; Link, 1983], adopting a form of *non-extensional* Mereology, in the sense of [Simons, 1987]. A *collection* is formed by assembling certain objects, called *parts* of the collection. Within this framework, both objects and collections of objects are seen as entities of the domain, i.e. they are represented by means of terms. A *part-whole* partial ordering relation on the domain $\succ$ (to be read *has-part*) is introduced, to relate collective entities with their parts. For example,

$\succ$ (beatles, paul) means that the entity *paul* is part of the collective entity named *Beatles*.

It is worth noting that such a mereological relation is *not extensional*; that is, a collection may not be equal to the sum of its proper parts; in other words, two collections having the same parts may *not* be equal. The $\succ$ relation cannot be equated to the $\supseteq$ relation of set theory, since the counterpart of the extensionality axiom does not hold.

To talk about pluralities, we define the *plural operator* '*':

Definition 1 (Plural Operator)

*P(a) iff $\forall x. \succ(a, x) \rightarrow (\exists y. P(y) \wedge (\succ(x, y) \vee \succ(y, x)))$

The purpose is to allow the construction of plural collective entities having singular objects of a certain type as their parts. More specifically, for any subpart 'x' of the plural entity, either 'x' is a part of the given singular type or the latter is part of 'x'. In this way we can define, for example, the plural predicate *PEOPLE* from the singular predicate *PERSON*:

PEOPLE $\equiv$ *PERSON.

An important feature of this theory is the possibility of defining generic predicates applying to collective entities. In [Franconi, 1993] the $\mathcal{D}$, $\mathcal{K}$ and $\mathcal{G}$ operators - called *plural quantifiers* - were discussed. They introduce the distributive, cumulative and group readings for generic unary predicates having a collection as argument.² They are *qualified* in the sense that the elements of actual predications are selected by a qualification predicate *C*. In this way, representational means are introduced to capture the semantics of the (possibly underdetermined) reading variants of NL expressions. As an example, take the possible "left" readings of the sentence *John, Paul, George and Ringo sing Yellow Submarine*. For the *collective reading* all the men together sing the song. In the case where each man sings separately, we speak of the *distributive reading*; it is expressed by means of the $\mathcal{D}$ quantifier which specifies that the relation holds for all the subparts of a certain type *C*. The *cumulative reading* can describe the mixed situations in which one sings alone, and separately the others sing together. It will be rendered by means of the $\mathcal{K}$ quantifier saying that the relation holds for some subparts including all the subpart of a certain type *C*. Finally, the *group reading* covers the case in which possibly only some of them sing; it is conveyed by the $\mathcal{G}$ quantifier which specifies that the relation possibly holds for some subpart of a certain type *C*; i.e. it expresses the group reading [Landman, 1989a; Landman, 1989b] as a sort of weakened collective reading. The plural quantifiers are formally defined as follows.

Definition 2 (Qualified Plural Quantifiers)

$\mathcal{D} C.P(a)$ iff $\forall x. (\succ(a, x) \wedge C(x)) \rightarrow P(x)$

$\mathcal{K} C.P(a)$ iff $\forall x. (\succ(a, x) \wedge C(x)) \rightarrow$
 $(\exists s. \succ(s, x) \wedge P(s))$

$\mathcal{G} C.P(a)$ iff $\exists x. \succ(a, x) \wedge C(x) \wedge P(x)$

It follows from the definition that cumulative plural quantified expressions are more general than non-quantified (i.e. collective) expressions and distributive plural quantified ones:

$\forall x. P(x) \rightarrow \mathcal{K} C.P(x)$

$\forall x. \mathcal{D} C.P(x) \rightarrow \mathcal{K} C.P(x)$.

In this way ambiguities in the readings can be preserved by using the cumulative operator.

3.2 More on the theory of events

Consider, now, an action, e.g. *eating*. Despite the fact that in this theory it can be (almost indefinitely) decomposed into smaller actions, there is a level below which we do not recognize eating events any more but, e.g., particular movements of the jaws or of the tongue, swallowing, etc... which do not intuitively qualify as actions of eating. Therefore, we assume that the extension of a predicate like *eat* in the domain of events (E_e) has *qualified atoms*, i.e. there are $e \in f(eat)$ (the denotation of *eat*) such that for every $e' \in f(eat)$, $e \succ e' \rightarrow e = e'$. Furthermore, for a given event, all its (qualified) atomic subparts are mutually non-overlapping and linearly ordered by $\prec$. With this in mind, the denotation of a perfective sentence is an event (or a collection of them) having proper (qualified) subparts. An imperfective sentence, instead, can be taken to refer to a collection of qualified atoms. This differs from many current proposals (e.g. [Kamp and Reyle, 1993]) where imperfective sentences are taken to denote states. However, it can be argued that imperfectives and statives only share some of their properties (e.g. the possibility of taking *for-* adverbials) but not others (e.g., states are homogeneous with respect to time, whereas imperfectives need not be so: e.g., the truth of *John loved Mary* at an interval, *t*, entails the truth of the same sentence at every sub-interval of *t*. On the contrary, the truth of *John was running* at an interval does entail that it was running at every sub-interval of *t*) and therefore must be kept conceptually distinct [Smith, 1991].

We assume that the objectual domain, E_o , has a structure similar to that of E_e , and hypothesise that, in certain circumstances, a homomorphism *h* maps elements of E_o into elements of E_e in such a way that the structure of the event domain is determined by the structure of the objectual one [Krifka, 1992]. The existence of such an homomorphism depends on the kind of thematic relations established by the verb; the direct object of an accomplishment verb is such an example [Dowty, 1991] calls it an *incremental theme*). According to this view, *telicity* is determined by: a) the existence of a perfective form; b) the existence of a particular thematic relation and c) the kind of object that enters this relation with the predicate (i.e. mass versus count). With this, the difference between accomplishment and activity sentences reduces to (b) and (c).

Achievements differ from both: crucially, even in languages like Italian the present tense of achievement predicates can never be imperfective. To account for this behaviour, we propose that: a) achievements never have proper

² For the purposes of this work, binary predicates will be used instead of unary ones.

(qualified) subparts and b) they are punctual (cf. [Dowty, 1979]).

3.3 States and time

With respect to times, we use an interval domain I whose connection with E_e is explicitly provided by means of a function τ assigning every event a time interval minimally containing it. We assume that the set of relations of [Allen, 1983] can be defined on I .

Contrary to events, states are not considered here as primitive objects (see [Kamp and Reyle, 1993] for discussion) but as derivative on times. More precisely, a VP like [*VP loves Mary*] establishes a set of intervals such that $\lambda x, t. \text{love}(x, \text{Mary}, t)$ is true; the whole sentence *John loves Mary*, in turn, requires that the interval S (the speech time) is such that $\text{love}(\text{John}, \text{Mary}, S)$ is true.

4 Applying the theory

In [Giorgi and Pianesi, 1991; Giorgi and Pianesi, 1992a; Giorgi and Pianesi, 1992b] it was proposed that each tense morpheme bears a precise *relational* temporal meaning. Furthermore, temporal (T) roles were introduced (cf. [Guéron and Hoekstra, 1989]), in analogy with thematic roles, as a (syntactic) device allowing positions in the thematic grid of a temporal predicate to be filled by temporal indices. Hence, a tense morpheme T-marks a VP, this way identifying one of its temporal argument with the temporal index of the VP. For instance, the English present tense morpheme, whose meaning is $S=R$, behaves like a one (free) place predicate, $= (S, T\text{-Arg2})$. By means of T-marking, T-Arg2 gets identified with the temporal index of the VP (R).³

When no tense morpheme is given, as in the Italian present tense, the temporal index of the AGR node (S) syntactically *binds* the temporal index of the VP; temporal binding entails a weaker relation than (temporal) equivalence, namely containment: $S \subseteq R$ (cf. [Pianesi, 1992] for an account of how this ideas could be implemented by means of an unification based grammar).

4.1 The present tense

First, consider the impossibility for present tense to convey a true perfective meaning (cf. Section 2). It has been suggested that this is so because of the punctual, i.e. durationless, nature of the speech time [Dowty, 1979] and the consequent impossibility of accommodating durative events within S . However, this explanation should allow for present tense perfective readings with otherwise punctual events (e.g. achievements) and in Section 2 we showed that this is incorrect. We will follow [Kamp, 1979] in defining *punctuality* directly on the eventive domain in such a way that it does not entail no duration. A qualification (cf. Section 4) will be added, in order to avoid picking up unwanted elements (i.e. events below qualified atoms). More precisely, an event e is punctual with respect to an event predicate, Q , iff there are no events in the extension of Q that partition e :

$$\bullet Q(e) \text{ iff } \forall e_1, e_2. (e \supset e_1 \wedge e \supset e_2 \wedge Q(e_1) \wedge Q(e_2) \rightarrow e_1 \supset e_2)$$

Let us now assume that the speech event, s , is punctual with respect to whatever predicate is given by the verb of the sentence. If the VP is perfective, it denotes a collection of individual events e having (qualified) atomic processes as subparts which are mutually non overlapping. Considering the way tense morphemes work, we end up with something like $S = \tau(s) = \tau(e)$ iff $s \subseteq e$ and $e \subseteq S$ (here $\subseteq$ is the relation of temporal containment on events; it can be defined as in [Kamp, 1979]). Therefore, there are e_1 and e_2 , $e \supset e_1$, e_2 in the extension of the event predicate that overlap s and do not overlap each other, leading to a contradiction. In an imperfective sentence, assuming that it denotes a collection of Q -atomic process $e_1, \dots, e_n$ and choosing one of them, e_i , there are no subparts of e_i in Q that may conflict with the punctuality of s , hence $\tau(s) = \tau(e_i)$ can be asserted.

Both the logical forms of perfective and imperfective sentences are examples of group reading. Consider (1).a and (2).a above. (7).i and .ii give the perfective and imperfective readings:

- (7) i) $(\mathcal{G}^h \text{Chicken} . V) \cap {}^h \text{Chicken}$
 ii) $(\mathcal{G}^h \text{Ed} . V) \cap {}^h \text{Chicken}$

where V is the verbal predicate $\lambda e. \exists t. (\tau(e) = t \wedge \text{eat}(e) \wedge t = \tau(s) \wedge \bullet \text{eat}(s))$ (we neglect the contribution of the Agent argument). Applying it to (7).i we get the collection of events which have a subpart, which is an event of eating a part of a chicken that is itself a chicken. Applying the predicate to (7).ii, we get the collection of events having a (Q -atomic) subpart that is an event of eating a part of a chicken. Note that: a) the fact that the direct object of *to eat* (*mangiare*) is an incremental theme entails that the image of *Chicken* under the object-to-event homomorphism is taken. b) The semantic contribution of the tense morpheme and of T-marking are embodied into the predicate V .⁴ Interpreting (7).i, a collection of events that have subparts is obtained, thereby violating the punctuality of s , and accounting for the general impossibility of perfective present tense events. c) The logical formula for imperfectives (7).ii mentions a predicate *Ed*. It is contributed by the lexical semantics of the verb and specifies the set of objects that are edible.

In Section 2 it was argued that the English stem of an eventive verb may only refer to perfective events, a property due to morphosyntactic properties of English. In this case, the denotation of $\mathcal{G}^h \text{Ed} . V$ reduces to that of $\mathcal{G}^h \text{Chicken} . V$, correctly representing the fact that English present tense does not allow imperfective readings. Actually, (7).i *per se* entails (7).ii in the sense that the latter is more general than the former. Therefore, something like (7).i is the logical form of an English sentence with an eventive verb, whereas (7).ii corresponds to Italian.

It turns out that the contribution of tense morphemes may be crucial in restricting the interpretation to a subset of

³ We do not commit ourselves to the Reichenbachian interpretation of R as the reference time [Reichenbach, 1947], but simply treat it as an argument of a temporal predicate

⁴ The V -predicate for Italian is obtained by substituting $t = \tau(s)$ with $\tau(s) \subseteq t$ in the expression for V ; see above.

(7).ii, e.g. by only allowing the imperfective reading (as in Italian) or by disallowing both (as in English). This approach can be extended to account for many other phenomena, e.g., the contrast between the simple past tense of languages like German and Dutch (cf. dutch *John at een appel* (=John ate an apple)), which can give rise to both perfective and imperfective readings, and the simple past of languages like Italian (*Gianni mangio' una mela* (= John ate an apple)) that only permit perfective ones. In the first case, the tense morpheme simply specifies the temporal relation between the speech time and the temporal index of the VP, and the logical form looks like (7).ii. In Italian, the simple past morpheme restricts the range of events provided by the verb, by selecting the perfective ones and giving rise to a logical form close to (7).i.

By way of illustration, we report the following sentence together with their logical forms

- (8) a) John runs
Gianni corre
($\mathcal{G}T_{run} \cdot V$) $\cap$ T_{run}
b) John eats
Gianni mangia
($\mathcal{G}^hEd \cdot V$) $\cap$ hEd

Both sentences have an imperfective reading in Italian that is impossible in English. With respect to the previous examples, note that: with intransitive activity verbs (*to run* in (8).a), the qualifying predicate is the top of the collection of the events of running (or a similar restriction brought in by the verb). In (8).b, where the intransitive form of a verb having an incremental theme is present, the homomorphic image of the set of edible object is taken. This way it is possible to account for the effects of the intransitivization process in a natural way, by directly resorting to the lexical semantics of the verb and without the introduction of free (or existentially closed) variables in the argument structure [Pianesi, 1992].

Habituals can be interpreted as stating the existence of an unspecified quantity of events, which apply to an unspecified quantity of objects (when an incremental theme is defined; cf. the SQA - Specified Quantity of A - feature of [Verkuyl, 1987; Verkuyl, 1989]; for habituals, see [Kearns, 1990]). The existence of an unspecified number of events will be rendered by means of the cumulative operator. Here is an example

- (9) i. John eats chickens
ii. Gianni mangia polli
iii. ($\mathcal{X}^hChicken \cdot V$) $\cap$ $h*Chicken$

(9).iii denotes the set of events that are the mereological sum of events of eating groups of chickens. Such events are under specified in the sense that it is not required for them to be in the extension of *eat*. Consider one of them, e , its time, $\tau(e)$, which is the convex closure of the time intervals associated with the single events e is sum of, and the set of intervals that are included in $\tau(e)$. (9).i and ii. say that the speech time corresponds to one of these intervals.

$$\lambda t. (\exists e. (\mathcal{X}^hChicken \cdot EAT) \cap *^hChicken)(e) \wedge t \subseteq \tau(e))(S)$$

Note that no contradictions due to the punctual nature of s arises, since it is not required that $S = \tau(s) = \tau(e_i)$ for any e_i which is a part of e ; hence, both (9).i and .ii are possible in English and in Italian, respectively.

4.2 The present perfect

In Section 2, it was shown that it is not possible to use locating temporal adverbials with English present perfect sentences. To account for these facts we use the notion of *consequent state* [Moens, 1986; Parsons, 1989]. Accordingly, the present perfect is seen as introducing a perfective event and a (consequent) state, holding in a set of intervals ranging from the conclusion (culmination) of the event and including S . The consequent state (and the perfective event) is introduced by the past participle morpheme, English *-en* and Italian *-t* [Giorgi and Pianesi, 1991; Giorgi and Pianesi, 1992a; Giorgi and Pianesi, 1992b]. Italian and English do not differ substantially with respect to the role of the participle morpheme. We attribute the different behaviour: (a) to the morphosyntactic properties of present tense (on the auxiliary) in the two languages and (b) to the anomalous status of bounded states. With respect to (a), in English we have an $S=R$ relation, whereas in Italian the syntactic binding gives rise to an inclusion relation. Concerning (b), [Kamp, 1991] points out that when the temporal adverbial locates the event, it establishes an *explicit* lower temporal bound on the consequent state which, therefore, behaves in a peculiar way. It, in fact, holds only on intervals that are similarly bounded.⁵ Consider now the following examples:

- (10) (i) John has eaten a chicken
(ii) Giovanni ha mangiato un pollo
(iii) * John has eaten a chicken at five
(iv) Giovanni ha mangiato un pollo alle cinque

The contribution of the verb plus the past participle morpheme is the consequent state of a perfective event:

$$\lambda t. \exists e. (\text{meets}(t, \tau(e)) \vee \text{after}(t, \tau(e))) \wedge P(e)$$

where $P(e)$ is ($\mathcal{G}^hChicken \cdot EAT$) $\cap$ $hChicken$. This is part of the meaning of all the sentences in (10). Interpreting the present tense of the auxiliary, we obtain:

- (11) i. $\exists e. (\text{meets}(S, \tau(e)) \vee \text{after}(S, \tau(e))) \wedge P(e)$
English
ii. $\exists e, t. (\text{meets}(t, \tau(e)) \vee \text{after}(t, \tau(e))) \wedge P(e) \wedge S \subseteq t$
Italian

where we have used the *meet* and *after* relation of [Allen, 1983]. (11).i and .ii are the logical forms for (10).i and .ii, respectively. If the contribution of the temporal adverb is taken into account, we first obtain:

⁵ For a different approach to this problem, see [Klein, 1992].

$\lambda t. \exists e. \text{meets}(t, \tau(e)) \wedge P(e) \wedge \tau(e) \subseteq 5$

i.e. only intervals that have a lower temporal bound complying with the location time are acceptable (*at five* is interpreted as denoting an interval including 5 o'clock). About the temporal containment relation between events and locating adverbials, see [Kamp and Reyle, 1993]. Finally:

- (12) i. $\exists e. \text{meets}(S, \tau(e)) \wedge P(e) \wedge \tau(e) \subseteq 5$
English
- ii. $\exists e, t. \text{meets}(t, \tau(e)) \wedge P(e) \wedge \tau(e) \subseteq 5 \wedge S \subseteq t$
Italian

which are the logical forms of (10).iii and iv., respectively. In the general case, the first formula is unsatisfiable, since S is required to meet $\tau(e)$ which, in turn, is contained in the 5 o'clock interval.⁶

5 Computing the Representations

Before concluding, let us briefly see how these representations could be built during parsing by considering a simple example. We assume a lexicon of stem and affixes. Verbal stems come into three fundamental varieties: statives, activities (including both the traditional activities and accomplishments) and achievements. With respect to thematic relation, we assume that those inducing an object-to-event homomorphism are stored in a list: Homomorphic-list = (Incr-Theme,...). The following is (part) of a possible lexical entry:

eat-
 pred: eat
 aspect: activity
 Θ-relation1: Agent
 Θ-relation2: Incr-Theme

When the thematic relation is in the Homomorphic-list, the value for the SQA feature of the object is percolated to the VP. Tense morphemes, as we saw, introduce temporal relations by means of T-marking (they may also restrict the denotation of the object they combine with; in a system based on, e.g., typed feature structures, this could be obtained by restricting the type of the VP [Sanfilippo, 1991]):

-s
 Cat: AGR/T
 Sem: [pred: =
 Arg1: S
 Arg2: < 1 >]
 Subcat: [Cat: VP
 Sem: [T-index: < 1 >]]

Interpreting syntactic structures, the application of the qualified plural quantifiers operator may be attempted on the

⁶The fact that this argument crucially relies on the width of the relevant intervals does not prejudice it, given the variable acceptability (at least for certain informants) of (10).iii when uttered few minutes after 5, say at 5:04

VP (the operator $\mathcal{K}$) or on the AGRP (the operator $\mathcal{G}$). Furthermore, there is a condition on $\mathcal{K}$ to the effect that it only applies to VPs whose SQA value is "-" or undefined.

Now consider sentence (2).a. The VP [*VP mang- [NP un pollo]*] inherits the SQA+ specification from the object NP thanks to the fact that the thematic relation is Incr-Theme; therefore, the $\mathcal{K}$ operator cannot apply. The further constituent to be considered is [*AGRP -a [VP mang- [NP un pollo]]*]. Its denotation is: $\lambda e. \exists t. (\tau(e)=t \wedge eat(e) \wedge \tau(s) \subseteq t \wedge *eat(s))$, where the inclusion relation between the speech time ($\tau(s)$) and the time index of the VP is due to syntactic binding (cf Section 4). Finally, applying the $\mathcal{G}$ operator, we get the logical form (9).i. As before, the perfective variant is impossible, given the punctual nature of s .

6 Conclusions

In this work, we have explored the use of a simple mereological framework to address several temporal and aspectual phenomena. The choice of a mereological approach is due to the necessity to talk about collections of events and about their parts, in order to accommodate linguistic data. An important result is that many differences between languages have been shown to reduce to lexical and/or morphosyntactical peculiarities, whereas syntax and semantics are ruled by the same principles.

Several issues still need to be considered within the mereological approach: the existence of atoms (entities which have no subparts), the possibility of using several different $\triangleright_i$ relations [Winston *et al.*, 1987] and the introduction of a mass disjunctive predicate as in [Link, 1983]. The first two points would be important to allow for more structured domains; this way, the differences between perfective and imperfective events could be stated more explicitly than it has been possible here. Disjunctive predicates, in turn, would permit to face the general question of homogeneity (a problem we did not address here) and give a more satisfactory status to states.

References

[Allen, 1983] Allen, J., F., Maintaining Knowledge about Temporal Intervals. In *Communications of the ACM*, 26, 1983.

[Allgayer and Franconi, 1992a] Allgayer, J. and Franconi, E., Collective Entities and Relations in Concepts Languages. In *Working Notes of the AAAI Fall Symposium "Issues on Description Logics"*, pages 31-35, Cambridge MA, October 1992. Also in *Workshop Notes of the ECAI Workshop on Theoretical Foundations of Knowledge Representation and Reasoning*, pages 1-5, Vienna, Austria, August 1992.

[Allgayer and Franconi, 1992b] Allgayer, J. and Franconi, E., A semantic Account of Plural Entities within a Hybrid Representation System, In *Proc. of the 5.th Intl. Symposium on Knowledge Engineering*, pages 305-312, Seville, Spain, October 1992.

[Bach, 1986] Bach, E., The Algebra of Events. *Linguistics and Philosophy*, 9:5-16, 1986.

- [Comrie, 1976] Comrie, B., *Aspect*. Cambridge University Press, Cambridge, 1976.
- [Comrie, 1985] Comrie, B., *Tense*. Cambridge University Press, Cambridge, 1985.
- [Dowty, 1979] Dowty, D., *Word Meaning and Montague Grammar*. Reidel, Dordrecht, 1979.
- [Dowty, 1991] Dowty, D., Thematic Proto-Roles and Argument Selection. *Language*, 67:547-619, 1991.
- [Franconi, 1993] Franconi, E., A Treatment of Plurals and Plural Quantifications based on a Theory of Collections. A preliminary version appears in the *Workshop Notes of the International Workshop on Formal Ontology*, pages 219-249, Padova, Italy, March 1993.
- [Giorgi and Pianesi, 1991] Giorgi, A. and Pianesi, F., Toward a Syntax of Temporal Representations. *Probus*, 2:187-213, 1991.
- [Giorgi and Pianesi, 1992a] Giorgi, A., and Pianesi, F., On Verbal Morphology in Germanic and Romance. In Fava, E. (ed.) *Proc. of the 7th Meeting of Generative Grammar*, Rosenberg & Sellier, Torino, 1992.
- [Giorgi and Pianesi, 1992b] Giorgi, A., and Pianesi, F., *Tense Interpretation and Morphosyntactic Structures in Germanic and Romance*, talk given at CGS8, Tromsø
- [Guéron and Hoekstra, 1988] Guéron, J. and Hoekstra, T., T-chains and the Constituent Structure of Auxiliaries. In Cardinaletti, A., Cinque, G., Giusti, G., (eds.), *Constituent Structure*, Foris, Dordrecht, 1988.
- [Kamp, 1979] Kamp, H., Events, Instants and Temporal Reference. In Bäuerle, R., Egli, U., von Stechow, A., (eds.), *Semantics from Different Points of View*, Springer, Berlin, 1979.
- [Kamp, 1991] Kamp, H., The Perfect and Other Tenses in French and English. In Kamp, H., (ed.) *Tense and Aspect in English and French*, Dyana Deliverable, R2.3.B, 1991.
- [Kamp and Reyle, 1993] Kamp, H. and Reyle, U., *From Discourse to Logic*, University of Stuttgart, (forthcoming).
- [Kearns, 1991] Kearns, K., S., *The Semantics of the English Progressive*. Ph.D. Thesis, MIT, Cambridge MA 1991.
- [Klein, 1992] Klein, W., The Present Perfect Puzzle. *Language*, 68:525-552, 1992.
- [Krifka, 1992] Krifka, M., Thematic relations as Links between Nominal Reference and Temporal Constitution. In Sag, I., Szabolcsi, A., *Lexical Matters*, Chicago University Press, 1992.
- [Landman, 1989a] Landman, Fred, Groups, I. *Linguistics and Philosophy*, 12:559-605, 1989.
- [Landman, 1989b] Landman, Fred, Groups, II. *Linguistics and Philosophy*, 12:723-744, 1989.
- [Lavelli et al., 1992] Lavelli, A., Magnini, B., Strapparava, C., An Approach to Multilevel Semantics for Applied Systems. In *Proc. of the 3rd ACL Conference on Applied Natural Language Processing*, Trento, Italy, 1992.
- [Link, 1983] Link, G., The Logical Analysis of Plurals and Mass Terms: a Lattice-Theoretical Approach. In Bäuerle, R., Schwarze, C., von Stechow, A., (eds.), *Meaning, Use and Interpretation of Language*, Walter de Gruyter, pages 302-323, 1983.
- [Moens, 1986] Moens, M., *Tense, Aspect and Temporal Reference*. Ph.D. Thesis, University of Edinburgh, Edinburgh, 1986.
- [Parsons, 1989] Parsons, T., *Events in the Semantics of English: a Study in Subatomic Semantics*. MIT Press, Cambridge MA, 1989.
- [Pianesi, 1992] Pianesi, F., Head Driven Bottom Up Generation and Government and Binding: A Unified Perspective. In Horacek, H., Zock, M., (eds.), *Proc. of the third European Workshop on Natural Language Generation*, Pinter, London, 1992.
- [Reichenbach, 1947] Reichenbach, H., *Elements of Symbolic Logics*. MacMillan, New York, 1947.
- [Roberts, 1991] Roberts, I. *Verbs and Diachronic Syntax*, ms., Geneve, 1991.
- [Sanfilippo, 1991] Sanfilippo, A., *Thematic and Aspectual Information in Verb Semantics*. Ms., Cambridge, 1991.
- [Simons, 1987] Simons, P., *Parts: A study in Ontology*. Clarendon Press, Oxford, 1987.
- [Smith, 1991] Smith, C., S., *The Parameter of Aspect*. Kluwer, Dordrecht, 1991.
- [Sowa, 1991] Sowa, J., F., Towards the Expressive Power of Natural Language. In Sowa, J., K., (ed.) *Principles of Semantic Networks*, Morgan Kaufmann, pages 157-189, 1991.
- [Verkuyl, 1987] Verkuyl, H., J., Non durative Closure of Events. In Groenendijk, J. A., G., de Jong, D., and Stokhof, M., J., B., (eds.), *Studies in Discourse Representation Theory and the Theory of Generalized Quantifiers*. Foris, Dordrecht, 1987.
- [Verkuyl, 1989] Verkuyl, H., J., Aspectual Class and Aspectual Composition. *Linguistics and Philosophy*, 12:39-94, 1989.
- [Winston et al., 1987] Winston, M. E., Chaffin, R., Herrmann, D., A Taxonomy of Part-whole Relations. *Cognitive Sciences*, 11:417-444, 1987.