Delmonte R.(1997), Lexical Representations, Event Structure and Quantification, Quaderni Patavini di Linguistica, 15, 39-93.

Lexical Representations, event structure and quantification

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Abstract

In this paper, we discuss the relation intervening between distributivity and the participants in an event. We argue that there is a strict dependency between aspectual features and the quantificational properties of each participantsin a given situation; we also argue for a distinction of events in terms of their polyadicity, or their number of arguments. In more general terms, we propose a principled way to deal with the problem of representing the structure of events and their relation with the situation and the participants in that situation.
At first we introduce a "static" description of predicates as conceptual representations in a computational lexicon, where event structure is expressed in terms of a combination of time “t” and event “e” which may assume a variable or a constant value according to aspectual class and to the number and type of arguments of the predicate. We hypothesize internal quantification on the event-time only whenever a variable is associated with “t”, and external quantification on the number of events only when a variable is associated with “e” in the static description.
Then we deal with “dynamic” quantificational properties of events which derive from syntactic and semantic properties of the utterance or situation in which they are contextualized. In this case we propose two main notions Global and Internal that apply to event structure and establish a point of view by means of which to decide whether temporal interpretation affects the overall event, or only portions of it; the two notions are also related to factuality of the event, and to its perfectivity. Finally, we discusse the introduction of a function that relates participants in the event according to their quantificational nature and the event structure itself. With respect to the subdivision of quantification into distributive and collective operators, we establish a mapping from participants into the event inward, and outward.

1. Introduction

At first we shall focus our attention on a particular problem pertaining to lexical semantics: the one of defining a lexical encoding adequate for the representation of event structure for event and state predicates. The lexical representation is regarded the static starting point to enable a text understanding system to compute final meaning representation where event or states may be assigned a dynamic interpretation according to syntactic and semantic properties of the current utterance.
In our attempt we want to link features belonging to a certain predicate, like aspectual and semantic inherent features, and quantification properties of event structure.
In Delmonte(1989) - but see also Carrier et al. 1993 - we presented a mapping algorithm that starting from a fixed number of classes and a syntactic encoding of argument structure could derive automatically via a certain number of linguistic rules, both grammatical function, semantic roles and conceptual representations. In our computational lexicon the following classes are present, starting from the lexical representations of verbs . In first column there is a code for lexical category, 1 stands for verb, 2 for adjective and 3 for noun. In second column we have syntactic classes, in third column aspectual and semantic classes, and in fourth column semantic and conceptual classes. After dash, there is a list of the arguments of the predicate each one separated by a dash again; a percent symbol introduces the list of selectional restrictions. This is an example (but see Delmonte, 1989),

1i. abbagliare	1 1 4 6 - 1 0 % 5 - 1 0 % 3 7
ii. abile	2 1 2 7 - 1 0 % 3 - 2 4 % 2
iii. allegria	3 3 2 e % 5 - 1 0 % 3 - 2 2 % 2 5

The classification regards an enlarged version of the frequency lexicon of written Italian which we call LIFVE, consisting in approximately 2000 verbs, 4000 nouns and 1000 adjectives which however amount finally to 12,000 entries when different contexts of use are taken into account.
The output of LIFVE is used by our system for text understanding GETA_RUN and for the generation of conceptual representations which will be commented further on in this paper (but see also Delmonte, 1995).

2. Interpreting temporal locations

In our model (see Bianchi & Delmonte) all entities and relations are assigned a spatiotemporal location which is made up of two indices: one index is bound to the main temporal location in the case of individuals. As to relations and modifiers of the main relation, the index for the time location is derived from the event/state time, i.e. TES. In turn, this index is in a given logical relation with the TES of the previous text span, the discourse focus: it may be BEFORE, AFTER, MEETS, OVERLAP etc. with it. The reference of the current TES is furthermore asserted to be included in some main temporal location which could be present in the previous text span. Thus, individuals receive directly a time index which bind their existence in the world and their properties, such as roles, or attributes, to some main temporal location; in case of names associated to individuals, we assign them to a universal location, in other words, we assume that in the domain specified by the text that name is used unambiguously to refer to a single well defined individual. This bipartition is quite natural: entities such as individuals or sets are assumed to be in a given time location for a longer stretch than the actual relation in which they are currently involved. The latter might be a punctual event, thus having a very short duration in time. Event properties are thus different from entity properties as to their temporal location.
Temporal interpretation is computed compositionally from the local features associated to the verb tense and the static lexical label associated to aspect, plus a number of relevant information like definiteness of the subject NP, and of the Object NP, plus their number. These features contribute to assigning a first dynamic aspectual label to the sentence in which the verbal predicate is analysed. This allows the system to compute local temporal relation intersententially, taking into adequate account all the elements which contribute to the definition of these temporal relations, which are essentially taken from Reichenbach's proposal. This computation is added to the f-structure of each clause - we follow LFG theoretical framework, where it will have to face the complexity arising from the presence of subordinate, coordinate and complement clauses. Finally, the result of the utterance temporal computation is passed on to the discourse module for temporal reasoning which is based on Allen's proposal(Allen, 1983). At this level, temporal intervals are generated and are attached

at nodes in a cluster. The logical notation introduced by Allen is perspicuous enough to allow for the overall representation of discourse structure, where reference intervals are generated by taking into account local logical relations.

2.1 Conceptual Representations

In accordance with the principle of meaning decomposition, we assume that concepts denoted by lexical items are made up of primitive concepts which can be expressed by the use of a very limited number of templates. The granularity of the description depends strictly on the (sub)domain and the aim of the task at hand. For instance, abstract concepts like “responsible” or “responsibility” when dealt with in a legal subdomain require a specification of preconditions which is different from what is expected in a generic domain (see Delmonte, Dibattista).

A method for the decomposition of lexical information should represent a principled way to organize a taxonomy of the concepts in a language, categorized by sets of features, which however are tightly interleaved with argument structure and the syntactic nature of each argument.

Basic constituents for our conceptual representations are spatial primitives on the basis of analogical relations existing in the spatiotemporal realm which is at the heart of the meaning of all verbs and deverbal nouns and adjectives. According to Jackendoff and Gruber, human beings seem to base their descriptions of any kind of experience on some crucial concepts drawn directly from what might be called the spatial semantic field. Similarly, temporal sequence is both perceived and expressed on the model of spatial sequence. Events and states are located in time - on a timeline - just as things and entities are located in space. The same prepositions are used both for spatial and temporal expressions.

In theory, it should be possible to describe the basic conceptual components of meaning of any verb given a finite number of spatial primitives and of modalities attached to them. Modalities describe a bit/portion of meaning of a lexical item when decomposed into conceptual primitive functions, and adds to them a certain modality. This is not to be confused with negation, which is itself an operator preceding and having scope over conceptual functions, as implied by the meaning of lexical items. We don’t have enough space here to describe our approach to conceptual representations in detail, we only say that it is a reduced version of the proposals by Jackendoff in his works (but see Delmonte, 1995).

The content of conceptual representation is as follows:

A. a set of primary functions which are, GO, BE, STAY, CAUSE, LET, ORIENT, IDENT and might all be preceded by negation NOT;

B. a fixed finite number of semantic fields distinguishing common areas of meaning in real knowledge of the world, like INFORM, POSSESS, EVAL, SUBJ, HYPER, PERCPT, MANIP, FACTV, MENT_ACT, PROPR, MEASU, POSIT, COERC, ASK, REACT, TOUCH, HOLD, HOLE, DIR, DIVID, UNIT, LET, etc.

C. a small number of directions indicators, FROM, TO, INTO, AGAINST, AT, TOWARD

D. a small number of secondary functions which are REP, TR

E. a finite set of modality operators with scope on the verb meaning and its complements, which include the following:

[exist, nonexist, major, minor, violnt, difclt, perf]

Finally, there is a generic evaluative polarity which simply accompanies the concept and encodes the way in which its meaning is perceived in a default manner as having a positive or a negative import: kill, die, destroy are computed as GO(TO[nonexist] X) negative); on the contrary create, be born, heal are computed as GO(TO[esist] X) positive) - they don't appear in this paper. The examples reported here are representatives of the various types of event structures generated in our computational lexicon:

derubare[CAUSE(<receiv>(GO(<possesn>(FROM<ex_owner>)))){(e1,tn),(e2,t2)]
dimostrare[LET(<agent>(GO(REP(<theme_unaff>(TO<perciv_a>))))){(e1,tn)}]
contrastare[CAUSE(<agent>(GO(AGAINST<theme_aff><instr_con>))){(e1,t1),(e2,tn)}]
costruire[CAUSE(<agent>(GO(TO[exist]<theme_eff>))){(e1,t1),e1,tn,(e2,t2)}]
esistere[BE(<theme_unaff>(STAYposit(AT))){(en,tn)}]
bussare[CAUSE-iter(<agent>(GOtouch(TO[<theme_a>))){(en,t1)}]
chiedere[LET(<address>(GO(REP(<informtn>(FROM<goal_a>)))){(e1,t1)}]

The event structure is automatically generated from aspectual information and is made up of two basic components: "e" stands for "event" and may be a single constant identifier, for instance "e1"; a variable like "en"; or a split value, where the event is partitioned into more than one subevent ordered sequentially in time, "e1... e2" The other component is "t", time which can be represented again either as a single constant value, as a variable or as a split value. In all such cases we understand time to be made up of intervals as Allen(1983) proposes; we also assume that events must be spatiotemporally located or anchored as is usual in Situation Semantics(see references to Barwise, Cooper). Finally we end up with seven such structures in occurrence of some aspectual well defined characteristic which will be commented in the following section:

2) 1. {(e1,tn),(e2,t2)}	for achievements (with a preparatory phase)
2. {(e1,tn)}	for activities
3. {(e1,t1),(e2,tn)}	for ingressive accomplishments
4. {(e1,t1),(e1,tn),(e2,t2)}	for accomplishments
5. {(en,tn)}	for states
6. {(en,t1)}	for iterable achievements
7. {(e1,t1)}	for achievements (with focus on result) or result_state

In what follows we will try to motivate this kind of classification and to verify its validity in actual contexts of use.

3. Aspect and the TD feature

The first topic we shall tackle is the procedure that assigns default classification to predicates in aspectual classes on the basis of syntactic classes. The main idea are simple: a transitive verb possesses an Agent as SUBJect an Affected Theme as OBJect and will be classified as an Accomplishment; the presence of an Unaffected Theme as Subject or as Object causes the verb to be classified as Stative. Unergatives are classified as Activities since they lack an OBJect argument and unaccusatives as Achievements. In addition, reflexives are assigned the same class as their corresponding transitive base form and inherent reflexives are computed as Achievements with an Affected Theme as Subject. Ergatives and passives derive directly from transitive verbs, and have an Affected Theme as Subject. However, default classification is not enough to account for a more fine grained subdivision of lexical entries. For instance, transitives may be computed as Statives, Activities or Achievements according to the kind of event denoted by the predicate, as happens with perceptive verbs. In turn Achievements have to be subdivided into subclasses in order to capture temporal inferences: one subclass, which may be called iterable achievement, overlaps with activities, and is used to account for predicates like, hiccup, sob, which does not result in a change of state, since, after a momentary change the subject recovers its previous state. Transitive verbs may be computed as transformative irreversible achievement which require a complete irreversible change in the theme, as for instance with a verb like "kill": in this case, the role Effected Theme might be instantiated, as happens with verbs of creation like build, create, or perceptual verbs like notice which do not simply indicate a change of state, possession, position or perception or information but introduce a new entity in the world. Finally, Accomplishments which denote a single event protracted in time, a preparatory phase and a culmination, may also have to be subdivided into two subclasses one of which denotes an Eventuality, i.e. a set of identical events, rather than a single event. The theme is expressed as a mass noun or as a plural NP: the eventuality is completed via a number of successive iteration of the same action, in order to affect the whole object: these are verbs like accumulate books, wash the dishes, taste or cook something, beat someone, screw, accompany, use, slice, help, feed, exercise, grow, water, drink, burn, follow, drive and so on.

In order to achieve a better mapping from syntax to theta-roles - and subsequently to conceptual representations in Jackendoff's style - the aspectual information has been used as an interface, and this interface has a nucleus which is constituted by the feature [±td]. A number of authors have argued explicitely, or implicitely, in favour of the existence of a feature [±t(emporally) d(ependent)] which should provide the basis for an adequate interface between syntax and aspectual semantics. Some of these authors include Roberts(1987), Tenny(1988), Hoekstra & Mulder (1990), Jackendoff(1990). Generally speaking, we might consider that for a given predicate to be +td corresponds to a possibility of being classified either as an Accomplishment or as an Achievement; whereas, in order to be classified Activity or State the opposite setting is required, -td. Thus, we can establish the following correspondances:

- 3i. +td = applies to predicates which introduce a change of state, position, information, or possession in the object; they can have a preparatory phase and an ending phase extending for a temporal duration; or they can be applied to predicates which describe punctual events, whose action is not protracted in time;

· ii. -td = applies to predicates which describe states. In case the predicate describes a process which has inherent temporal duration then no change must be associated with the same predicate. These are all computed as activities.

This classification is used mainly to build up the event structure associated to each predicate, following the suggestions made by Pustejovsky(1992), except that we derive the whole system from the interaction of syntactic classes with td feature, imperativity and ingressivity, rather than building up each representation from scratch.

1. Table of Lexical Mapping Principles for Aspectual Properties of Predicates

syntactic class	**+td**			**-td**
	+imp		**-imp**	
	+ingres	**-ingres**		**+ingres**
a. transitive	Achiev	Accomp	Activity	Stative
b. unergative		Accomp	Activity	Stative
c. unaccusative	Achiev	Accomp		Result_State
d. copul/raising		Accomp		Stative
e. psych I			Activity	
f. reflexives	Achiev		Activity	
g. inherent_refl	Achiev		Activity	Result_State
h. ergative		Accomp	Activity	
i. impersonal				Result_State
j. atmosph.			Activity	
k. psych II				Stative

In addition, we have the following combinations between sintactic and aspectual classes:

4) a. transitives: Ingressive Accomplishments;
b. transitives, unaccusatives: Irreversible Transformative Achievements;
c. unergatives: Iterable Achievements;
d. process verbs: Abortives; Continuatives; Completives; Iteratives.

These are the event representation proposed in Pustejovsky(1988), who subclassifies events as State, Process and Transition:

5) 1. STATE(S): sick, love, know [S e]S
2. PROCESS(S): run, push, drag [P e1 ... en]P
3. SIMPLE TRANSITION: give, open, close [T e1 ... en]T
4. LOGICAL TRANSITION: build, draw, destroy [T [P* e1 ... en]P* e]T
5. CULMINATING TRANSITION: die, lose, win, arrive [T [P e1 ... en]P e*]T
6. PROCESS TRANSITION: throw, drop, mail, send [T [P e1 ... en]P e]T

Our representation presented under 2. above is made up of seven subclasses rather than six, and captures the fundamental features underlying Pustejovsky's argument, while organizing event structures in relation to temporal computation. Inferences can now be drawn as follows:

a. accomplishments give rise to inferences which view the affected theme in two different states, e1 at t1 when the object existed in its primary unchanged state, and e2 at t2 after the action denoted by the predicate has been fully carried out, when the object undergoes a change of state. Intermediate events have no relevance even though they may have some, in case the action or the process is abruptly interrupted and the accomplishment is not carried out, so that the event en suddenly becomes relevant in the sense that if realized, it prevents e2 to be accomplished;

b. states, possess no internal structure;

c. achievements are made out of a indefinite number of preparatory events which however have no relevance: the "head" event is the final one, when something is actually achieved;

d. activities have internal structure only from a temporal point of view in the sense that they possess the subinterval property: in case the activity is interrupted, say at tn=t3, the inference we draw is that the event has already taken place: i.e. the "head" event is at the beginning. In addition, we also want to infer that at an intermediate time, tn=t2<t3, the subject was engaged in that activity;

e. achievements-iterable, are just punctual achievements with no preparatory phase, which introduce no change of state in the world, in that the subject returns to its previous state every time the achievement is realized;
f. accomplishments-ingressive, whose "head" event is at the beginning, and then they have an eventuality which is usually an iteration of the same process but which, either does not state that the change of state in the object will actually take place, or it applies to a mass noun or a plural noun;
g. achievements with focus on result which present a new entity in the world and require at the interpretive level that the final state has actually taken place.
h. finally, accomplishments which do not only introduce a change of state but also introduce a new entity in the world, like "build, draw, create...", they make it to come into existence.
Inferences on spatio-temporal locations of the participants in the situation are computed after all syntactic and semantic computations have been successfully carried out.

4. Quantifiers and Interpretation

The computation of quantifier scope is one of the central problems to be solved when building a general system, as Cooper comments (1991, 39): however, there is then the further problem of what to do with the correct scopings thus obtained. It is clearly much better to have QR rather than not having it. However, scopings is not all there need to be as to contextual information necessary to compute quantified interpretation: in particular, in the case of indefinite NPs local information might not be sufficient. The relation intervening between quantifiers and interpretation in our framework, can be summarized as follows:
i. since we work from a linguistic perspective, we assume interpretation to be the by-product of the processes independently set up by a certain number of modules organized in a feeding relation which might be paraphrased as follows: lexical properties of categories and predicates associated with the input sentence conspire to produce an adequate syntactic and functional representation for the utterance which contains all information to be passed to discourse and interpretation modules;
ii. quantification may have scope over the event and thus contribute to a quantified interpretation of the event.
ii. generic statements are treated as non-factive clauses in that they don't contribute direct facts to be added to the model: their main relation is quantified over by some temporal quantifier that suspends its extensionality in space and time, and quantifies over spatiotemporal locations (see Barwise, 1985:3).
Event structure is used for quantifications on the event(see Delmonte,1994) which may affect either the time "t" or the event "e" in case they have "n" as index. Thus activities allows quantification on temporal extension, whereas iterable achievements on the number of events; quantification on achievements implies a repetition of the event at a different time location, or in case of achievements on the preparatory phase; accomplishments only allow quantification on the internal process. States allow quantification both on the number of events and on time extension. For instance an adverb like "little, much, enough" may quantify on time extension with activities, but it quantifies on events with iterable achievements:
6i. Gino ha dormito poco
ii. Gino dorme spesso supino
7i. Gino ha tossito poco
ii. Gino tossisce spesso
8i. Gino ha raggiunto in fretta/*abbastanza l'ufficio
ii. Gino raggiunge spesso l'ufficio in fretta
9i. Gino ha scritto in fretta/*abbastanza l'avviso
ii. Gino scrive spesso l'avviso in fretta
10i. A Gino piace poco/spesso
In turn, quantifiers and quantified NP may contribute either a collective or a distributive reading for the participants in the event denoted by the main relation. This will cause participants to be involved in a single event or in multiple events according to the semantic features of the main verbal predicate. We shall deal with the role of participants and their semantic nature, and then pass to the problem of interpreting the internal structure of the event in which participants are involved.

We also want to establish some criteria to account for the interaction existing between the interpretation of the event/participants relation as defined above and the internal structure of the event. How is the mapping from participants to event structure related? Should we use the previous interpretation to map it onto the event structure as it is computable locally? In other words, what is the procedure that leads us from the interpretation of the participants/event function to the interpretation of the event structure?
There are a number of grammatical phenomena which are heavily sensitive to temporal dependence and which have been discussed in the literature above (but see also Delmonte 1992): selectional (in the case of arguments) or semantic (in the case of modifiers) restrictions operating on secondary predication like resultatives, optional open complements, open adjuncts; semantic constraints on the use of bare NPs.
An important element of discrimination is constituted by the presence in the subject and/or in complements of elements such as indefinites, that may have an influence on the aspectual properties of the predicate, even though they have no intrinsic aspectual meaning.
An object NP constituted by an indefinite mass noun gives rise to a context in which a transitive verb labelled in the lexicon as an "accomplishment" or an "achievement" acquire the same properties as an activity. The same can happen if the object NP is a plural indefinite noun.

11)1. John was running when he died.
2. John ran before dying.
3. John was building houses when he died.
4. John built houses before dying.
5. John was drinking beer when he died.
6. John drank beer before dying.

12)1. John was building a house when he died.
2. John built a house before dying.
3. John was drinking a beer when he died.
4. John drank a beer before dying.
5. John was running to the doctor when he died.
6. John ran to the doctor before dying.

In 11) we see that 2, 4 and 6 are correct inferences respectively from 1, 3, and 5; on the contrary, in 12) 2, 4 and 6 do not constitute correct inferences respectively from 1, 3, and 5.
We can say then that an indefinite mass noun in the object NP of a transitive verb labelled as an accomplishment or an achievement brings about a relabelling of the predicate as an activity, while a plural indefinite noun causes the analysis to proceed along two parallel paths: one that gives the predicate the same aspectual label as its verb, and the other that labels the predicate as an activity, with the additional aspectual features "iterated" and "indefinite" to signify the indefinite iteration of the event implied by this reading of the sentence.
Similarly, a plural indefinite subject NP modifies the aspectual interpretation of a predicate whose verb is an achievement. In this case, the event is interpreted as being iterated and the predicate acquires the properties of an activity. It is thus labelled as such, with the additional features "iterated" and "indefinite".
Aspectual classes can be used to constrain the behaviour of passives which contributes perfectivity to the predicate meaning: an activity verb like "mangiare", is no longer interpretable as an activity but only as an achievement. The impossibility to use a bare NP as a subject or as an object in this case, must be linked to the aspectual nature of the verb, which is expressed by the voice. In other words, the ±td parameter may be associated either with the lexical entry, the inflected form or the voice, inherited via lexical mapping principles. As a general rule we might introduce the following principle: a passive subject must be individuated. The following examples are due to Belletti(1986):

13a. Gli studenti sono stati considerati intelligenti
b. I bambini sono stati ritenuti divertenti
c. Le lettere sono state scritte per l'ufficio

14a. *Studenti sono stati considerati intelligenti
b. *Bambini sono stati ritenuti divertenti
c. *Lettere sono state scritte per l'ufficio

The aspectual category of a predicate may be also modified by other complements beside the subject and object. If the VP expresses an activity or behaves aspectually as such,

its aspectual category can be changed by phrases expressing specific destination, distance to overcome or completion of the action. Such complements confer telicity on the predicate, which takes on the same features and entailments as an accomplishment as proven by 11/12. The predicates labelled as activities, that are modified by these sorts of phrases and thus acquire telicity, are relabelled as accomplishments.
Temporal Dependence is extended to modifiers like adjectivals used in primary and secondary predication and manner adverbs: both categories can be predicated either of the OBJect - thus inducing temporal dependency - or of the SUBJect thus simply describing a property of the SUBJect. Consider the following paradigm:

15a. *Non consideravo studenti intelligenti
b. *Non ritenevo bambini divertenti
16a. *Sono considerati alcuni/gli studenti intelligenti
b. *Sono ritenuti gli/alcuni bambini divertenti

as opposed to,

17a Ho scritto (le) lettere per l'ufficio
b. Non considero gli studenti intelligenti
c. Non ritengo i bambini intelligenti
18 a. John has become very tall
b. Mary has seen John drunk
c. John ate the meat raw/Jack served the drinks cold
d. Frank considers Tom intelligent
e. Ann left the room sad
f. Sam is bald/Simon seems happy
19a. They hammered the metal flat/Tim painted the house red
b. John made Mary angry

There is a clear difference in status between the adjectives in 19. and those in 18.: the former are obligatory or optional complements of a predicate which involves change of state, and an AGENT as SUBJect; the latter are optional or obligatory complements of predicates which do not involve such a change of state. Thus no temporal dependency may be inferred. The example in d. is a case of lack of temporal dependence owing to the nature of the predicate CONSIDER, a propositional attitude verb which represents the attitude of the SUBJect towards the OBJect NP. In LFG terms, this NP is computed as a non-argument function, interpreted as the SUBJect of the open complement "intelligent" which semantically selects it. The adjectives contained in a. b. c. all denote states: however, "tall" can be regarded a permanent state which can be modified with some difficulty! Raw, cold and drunk on the contrary are temporary states which denote a particular condition associated to the OBJect NP, thus temporally dependent in their interpretation.
As we shall see, to take these differences into account we use an accurate lexical classification, as well an efficient grammatical parser which associates modifiers to the appropriate complement. State-descriptive predicates, or Carlson(1977) stage-level predicates are selected by these XCOMPs: naked, tired, sick, drunk, open, insane, crazy, orange, fat, smart in the same way in which Property-predicates, or Individual-level predicates are disallowed from entering an XCOMP in case it is controlled by a temporally dependent OBJect: tall, bald, boring, intelligent.

5. Global vs Internal: two features for event structure

The interaction of the syntactic realization of arguments of a predicate with its aspectual properties must then be filtered through the additional contribution made by tense. Constraints coming from aspectual classes interact with tense specifications and with the syntactic realization of arguments to give as a final result a bipartition into two main interpretive classes for the whole utterance: these classes have been traditionally discussed in the literature as the perfective/imperfective opposition. We shall reformulate this subdivision in the following section by two different but related features, global vs internal view. We shall now discuss the nature of this bipartition from a traditional perspective.
The perfective/imperfective opposition can be considered a universal linguistic principle, which can find different realizations in the verb or lexical case systems of particular languages. Perfectivity indicates the view of a situation as a single whole, without distinction of the various separate phases that make up that situation, while the imperfective pays essential attention to the internal structure of the situation.
This conceptual distinction obviously applies to any situation described in any natural language, regardless of how or if a particular linguistic code may express it

morphologically, syntactically or lexically. Dahl incorporates the concept of boundedness in that of perfectivity:
"... a perfective verb will typically denote a single event, seen as an unanalyzed whole, with a well-defined result or end-state, located in the past. More often than not, the event will be punctual or, at least, it will be seen as a single transition from one state to its opposite, the duration of which can be disregarded..."(1984:13).
As appears from the context, Dahl applies perfectivity to past situations. It stems from the observation that virtually all the languages screened in the survey have both perfective and imperfective forms to refer to the past but use mainly the imperfective ones to refer to the present. This is a direct consequence of the fact that a situation described in a perfective form is perceived as bounded, that is to say as having a definite result or endpoint. Present situations have not reached an end when they are communicated and consequently cannot normally be considered as bounded. Only momentary actions may be taken to have already reached an endpoint when they are described, and thus a number of languages express them in the perfective. For the same reason, it is also quite common to use perfective forms for performative verbs and for descriptions in the so-called historical present.
The property of boundedness associated with perfective descriptions allows far-reaching generalizations. Only accomplishments and achievements, in fact, express by definition bounded actions, since they represent events that bring about a specific result or that have a definite end. Thanks to this property, they are often labelled aspectually as [+telic]. Activities and states, on the other hand, are [-telic], since they specify no goal to be reached. Thus, predicates belonging to the latter two verb classes are expected to behave differently from accomplishments and achievements when they are in a perfective form (if they can appear in such a form at all). We shall check this prediction by means of a few examples. In English, the perfective/imperfective opposition is realized mainly in the verb system. The Simple Past Tense, for instance, is aspectually marked as [+perfective], while the Past Progressive is imperfective, that is to say [-perfective]. Thus, a sentence like:
20. Helen wrote a letter at 11 o'clock
conveys a perfective view of the accomplishment, whose internal constituency is not analysed. According to the definition of perfectivity given above, the duration of a perfective event is disregarded. This stands out clearly in 40, since the process of writing a letter has intrinsic duration and Helen was presumably still engaged in it at some time after 11 o'clock; however, the perfective form of the verb is compatible with a punctual temporal expression, which proves that the accomplishment is perceived as having virtually no duration.
The same accomplishment can be described by using an imperfective form, as in:
21. Helen was writing a letter at 11 o'clock.
Here the process is considered without any reference to the attainment of its endpoint. The imperfective aspect can then be exploited to emphasize the duration of an event, forcing the hearer to concentrate on its internal structure rather than on its result.
The examples considered confirm that an accomplishment can be described either in a perfective or in an imperfective form without any special restriction. The aspect actually used therefore corresponds to a choice operated by the speaker. Achievements are also [+telic] and are consequently expected to behave in a similar way with respect to the aspectual category of perfectivity. However, while iterable achievements can be viewed internally - like "knock" -, real achievements can't. Achievements capture either the inception - like "find, lose" - or the climax of an act with some preparatory phase, and therefore have no duration at all. If an achievement is instantaneous, its beginning virtually coincides with its end. This implies that an achievement entails its result and therefore, from a linguistic point of view, its internal constituency is irrelevant.
The only way in which achievements can be considered as imperfective, that is to say as having no completion, is either to take into consideration a sequence of them or to focus on the time immediately preceding their realization. Thus:
22. The bus was stopping
can be paraphrased as: "The bus was about to stop". In this case, the achievement is the endpoint, the final instant of the time interval considered. Something may still occur at RT or between RT and the achievement time that prevents the achievement from happening.
It is difficult to see how an activity, which is [-telic] since it describes an event that involves no culmination or specific result, can be considered as "an unanalyzed whole, with a well-defined result or end-state". The acceptability of sentences like:

23. John ran at 11 o'clock,
however, forces us to conclude that also activities can appear in perfective forms. It must be noticed that the perfective form somehow limits the activity: in 23., the invited inference is that John participated in a particular running-event at 11 o'clock. The sentence would also be appropriate if it were the case that John ran for some time at about 11 o'clock. The run is then seen as a temporally limited event whose duration is not important, so that it can be conceived as contemporaneous with the punctual RT expressed by the temporal adverbial. Nevertheless, not all activity verbs can appear in the same context, as exemplified by:
24. *Helen wrote at 11 o'clock.
The parallel imperfective sentences, on the other hand, are perfectly normal, as proved by:
25. Helen was writing at 11 o'clock.
26. John was running at 11 o'clock.
This is not exceptional, since nothing prevents an activity from being expressed in an imperfective form. It is in fact an essential feature of imperfectivity that it does not entail the completion of the event described.
Sentences like 46., however, prove that activities can occur in the Simple Past, which we defined as a perfective tense. One may want to dismiss 45. as an accomplishment use of an activity verb (especially if it is taken to mean that John took part in a sports event), but sentences like the following can only express genuine activities:
27. (What did you do at the party?) We danced.
The English Simple Past can also convey an imperfective meaning for the occasion: 27. refers to a single activity, located in the past and seen as an unanalysed whole, whose duration is disregarded. The PP "at the party", and perhaps the perfective form itself, specifies that the activity corresponds to a particular, bounded situation. All the requirements of perfectivity are therefore met, since, even though there is no defined result of the action, its endpoint is implicit in the utterance. In fact, if it is assumed that a situation is a state, an activity, an accomplishment or an achievement not because of its ontology but simply because language describes it as belonging to one of these four categories, then situations are not in themselves perfective or imperfective: they are described by our linguistic codes as such, and different codes may present conspicuous dissimilarities.
State verbs are similar to those describing activities in that they are [-telic] and may be expected to display a similar behaviour when they are in a tense aspectually marked as [+perfective] such as the Simple Past. However, while it is clear that not all activities can appear in a perfective form, stative verbs generate perfectly acceptable sentences when they appear in the Simple Past, as exemplified by:
28. John was young
29. John was in London
30. John had a cat
31. Methuselah lived 969 years.
Yet, not all the sentences 28-31 are undoubtedly perfective. In fact, only the verb in 31. is unequivocally [+perfective], since it expresses a past state with a well-defined duration, seen as an unanalysed whole. Examples 28-30 describe past states whose internal constituency is not analysed either, but lack the boundedness of 31. Thus, it is impossible to say whether these sentences are perfective or imperfective, as they present properties of both aspectual categories. They can then be assumed to be ambiguous between a perfective and an imperfective interpretation.
Coming now to temporal adverbials, we see that frequency adverbials yield unacceptable sentences if they modify permanent states, i.e. states that in the natural course of things cannot end before the death or disintegration of the subject, or irreversibly transformative achievements, as shown by,
32. *John is tall every day.
33. *John often kills Mary.
As various verbs can express either activities or accomplishments in different contexts, several tests have been worked out to separate the former from the latter. They all show that ADJuncts are an essential component of the temporal-aspectual representation and of the inferential processes.
34a. ?John painted a picture for an hour.
b. John painted a picture in an hour.
c. It took John an hour to paint a picture (accomplishment).
35a. John walked for an hour.

b. *John walked in an hour.
c. ?It took John an hour to walk (activity).

Even though 34a and 34b can be accepted in some contexts, their meaning is very different from that of their more common counterparts. 34a can in fact be roughly paraphrased as: "John painted at a picture for an hour", meaning that John did not paint a whole picture; while 34b means that John did paint the picture. Analogously, 35a implies that John had a walk, while 35b could only mean that it took him an hour to start walking. The paraphrases in c. with "take an hour to.." apply then naturally to the grammatical and most acceptable examples, i.e. 34b. and 35a. This test brings to the light a peculiarity of accomplishments, since stative verbs cannot appear in this construction and achievements are interpreted semantically like activities:

36. *It took John an hour to know the answer.
37. It took John an hour to notice the painting.

Another interesting case is the use of "interrupt" which fits naturally with activities and accomplishment, giving however different inferences. In,

38. John was walking when he was interrupted.

we imply that "John walked"; while from:

39. John was painting a picture when he was interrupted.

it is inferred that: "John did not paint a picture". As achievements capture either the inception or the climax of an event, they are represented by language as having virtually no duration. This is the basic concept that underlies the tests for achievement verbs:

40. John noticed the painting in ten minutes.

entails: "Ten minutes elapsed before John noticed the painting", rather than:" *John was noticing the painting during ten minutes".

6. Factuality and the Structure of Events

Factuality can be regarded as the main features that contribute to the meaning conveyed by an event. In other words we want to ascertain whether a given event has actually taken place in a given spatiotemporal location, and whether it has come to an end or not. This is clearly orthogonal to the interpretation of the participants in the event: in case the event is not factual, then some of its internal arguments may not be factual themselves. Also, in case the event is not completed, we may have to assume that some of its internal arguments are not "completed", or are entities not fully realized in the world. In particular, both states and activities may point to bounded spatiotemporal locations, and their events are thus fully completed in the past, for instance. As to achievements we saw that they might be viewed from the moment immediately preceding their realization, thus indicating that some goal may not have taken place. Also accomplishments, having clear internal structure, may indicate events which have begun, or are in the course of realization but are not completed: in this case, some entity may be in completion and being not fully realized does not constitute a factual individual. A number of inferences should be drawn in the model whenever some of these event structures are realized: in particular, an event may continue a previous ingressive event, in case it is an accomplishment; an event may complete a previous incomplete event; states and activities may have an end and a change of state/activity may take place with an egressive or completive process verb like "end, finish". In addition, all four classes may constitute habitual and/or iterated events, or even generic events, which however are non factual.

In line with the subdivision of predicates into perfective and non perfective discussed in the section above, we make the hypothesis that there are two features by which events contribute to the interpretation of the clause in which they are contained: Internal vs Global. The internal view only allows us to see one interval of the global event, whereas the global view gives us a complete view of the whole event. In turn, the internal view may be specified as Internal-Ingressive in case the event has just begun, or Internal-Egressive in case it is almost finishing. In addition, we need an Internal-Iterated, for iterable events when viewed from an internal view; and a Global-Iterated for iterated events viewed globally. Finally, Global-Nonfactual for all generic and habitual events, but also for intensional predicates, conditionals, and those expressing some modality. We also need an Internal-Nonfactual for all accomplishments which express and event that has not come to an end, thus implying that its internal argument cannot be computed as a factual entity in the world. Finally we need a Global-Egressive and a Global-Process for characterizing the type of event where a process verb governs a semantic lexical predicate, modifying its meaning concurrently.

Thus, we ended up with ten possible classes of events which should allow us to express all possible combinations of meaning compositionally built from tense, aspect, temporal adverbs and other elements of the proposition under analysis. We shall now illustrate with examples how the classification captures the relevant features of event structure.

A. Internal-Egressive -> Only with achievements with a preparatory phase

41a. The bus was stopping.
   b. L'autobus si stava fermando / *L'autobus stava fermando
   c. John is killing a woman.
   d. John is dying.
   e. When I arrived at the station, my friends were leaving.
   f. Quanto il treno partì, Gino stava arrivando.

In Italian, the inchoative inherent reflexive class of the same underlying verb should be chosen. "Fermare" does not possess an ergative alternation, which could allow the required egressive reading.

B. Internal -> Only process verbs

42a. John is running.
   b. John was being a fool.
   c. John was walking when he was interrupted.
   d. John was painting a picture when he was interrupted.
   e. John was running at 11 o'clock.
   f. John is drinking (a beer).
   g. John is loading hay on the truck.
   h. John loves Mary.

As we noted above, with the exception of b. which is only allowed in English - and marginally - the remaining cases regard verbs with time as a variable (tn), i.e., we are viewing always activities and accomplishments. States, since do not have temporal boundaries always allow internal views: however the examples has at least two possible interpretations: 1. John loves Mary now; John is involved in a loving state with Mary and this lasts for an unbounded time period.

C. Global -> All classes are allowed

43a. The bus has been stopping all the time.
   b. John painted a picture (in an hour /at 11 o'clock.).
   c. John walked (for an hour / at 11 o'clock).
   d It took John an hour to notice the painting.
   e. John hit a woman.
   f. John knocked at the door (at 11 o'clock).
   g. (What did you do at the party?) We danced.
   h. John was young / in London.
   i. John has/had a cat.
   l. John lived 969 years.
   m. John loved Mary.
   n. John sang (Hey Jude)/ for hours.
   o. John read stop on the traffic lights.

Notice that the use of simple past may override static specification for lexical entries like stative "love", or activity "sing" and generate a bounded reading of the event.

D. Global-Iterative -> Only temporally bounded events

44a. John discovered quaint little villages for years.
   b. John hit every woman/(all) the women.
   c. John ran every morning last week.

Activities may be included but not stative verbs.

E. Internal-Iterative -> Only with iterable achievements

45a. The light is flashing
   b. John was knocking at the door at 11 o'clock.
   c. John is hitting a woman

F. Internal-Ingressive -> All classes allowed except for punctual achievements

46a. The two little pigs began to run as fast as they could.
   b. John started to love music when he was a child.
   c. Le patate hanno iniziato a bollire.
   d. John started to collect his books.
   e. John started writing a book this morning.
   f. John started to understand what she said.

G. Internal-Nonfactual -> Only with accomplishments.

47a. John is building a house.

b. John is loading a truck with hay.
c. Jimmy began to build his little house.

H. Global-Nonfactual -> All classes

48a. John will love Mary.
b. John wants (to buy) a car.
c. John plays football every weekend.

I. Global-Egressive -> Only for (ingressive) accomplishment

49a. John finished reading his book
b. John finished washing the dishes

L. Global-Process -> All process verbs

50a. John stopped/continued loving Mary
b. John stopped/continued reading
c. John stopped/continued building his house
d. John stopped/continued washing the dishes

Stopping the process involved in an accomplishment implies the denial of the factual realization of the event; on the contrary, continuing a process in an accomplishment instantiates a new starting point in time. As to activities and statives, an end point or a lower boundary in the time interval related to the predicate meaning is imposed at the current reference time.

From a cursory view at each classification, we may conclude that there is a strong relationship between broad aspectual classes and factuality. Thus we may group the above classes into two subgroups: 1. Global-Nonfactual, Internal-NonFactual, Global-Process, on the basis of which Factuality depends; the remaining classes, which determine features of the interpretation. The question we pose ourselves now, is the following one: what are the interpretive properties of these classes, and are the two basic parameters semantically founded?

Krifka (1992),proposes to define general interpretive conditions for event structures from the similarity in semantic behaviour between nominal and verbal predicates. He postulates the existence of two reference classes, Cumulative and Quantized, by which verbal and nominal expressions are assigned a denotation: this is achieved by a purported semantic similarity of their underlying concepts. Thus, Cumulative concepts have an interpretation by which no set terminal point may be assumed for events; in the same way, if we assume a spatial mapping for objects, we may say that there is no set border for Cumulative objects. The same reasoning, in reverse, may be applied to Quantized concepts related to events and to objects. A number of properties may then be associated with these two classes and a number of restrictions will apply to event types from the interpretation of objects: for instance, Uniqueness of Object requires Uniqueness of Event, i.e. if I drink a glass of wine, there will only be one drinking event, even though the drinking event may be characterized internally by a number of subevents which however must have the same Set Terminal Point, and these are all interpretable as part of the overall Unique event of drinking. However, if I drink wine, there will be no Uniqueness of Object and consequently no Uniqueness of event. In the former case a Quantized Object restricts the interpretation of the event as being Quantized; in the latter case a Cumulative Object restricts the interpretation of the event as being Cumulative. The core of the interpretative scheme is thus the part-of relation which can be postulated for Quantized concepts, as opposed to Cumulative concepts, in relation to the notion of temporal and spatial constitution of an Object which is qualifiable as possessing a Set border, and for an Event a Set terminal point in case it belongs to Quantized concepts.

The two notions introduced by Krifka are important, but are not sufficient in our view to interpret all the features present in event structures of a given context or situation.

7. Event Structure and Quantification

There is a further semantic dimension that must be highlighted in the process of interpreting the meaning of an event and this is strictly interrelated with its internal structure and with temporal interpretation. In the preceding section, we saw how tense specification may alter the import of aspect on the interpretation of the event constituted by the main verbal predicate: we analyzed each aspectual class and related it to properties like perfectivity and the subinterval property, which should belong only to events which have some internal structure, i.e. accomplishments and activities. However, we were forced to admit that in order to compute the overall meaning of a given event there is a number of elements like tense, definiteness of the NP Object,

temporal adverbial adjuncts which contribute to modify semantic properties associated to the static lexical meaning of the main verbal predicate.
Generally speaking, we assume that states and activities are distributive if not specified otherwise by some collective operator like "together"(see Lasersohn,1990). Generic statements with an explicit distributive marker, "each" indicates that there is a one to one mapping between its participants, for all occurrences of that relation in a given spatial location and for all temporal locations. As Lasersohn comments, the operator "together" may contribute in assigning a collectivizing interpretation to the relation, thus meaning that the participants are to be regarded as a group: our function will then be an "all-to-one". On the contrary, if we consider states such as "sit", and a sentence as "John and Mary were sitting", we want to infer that both John and Mary were in a given state, independently of one another. Motion predicates usually also must be understood as distributive in meaning: thus the sentence "John and Mary are running together", should be interpreted with the operator "together" indicating spatial or local proximity, i.e. as a function on spatial location rather than as a function on the main relation. Anyhow, both achievements and accomplishments require some knowledge to understand what is going on. Notice that the same selective import that "together" has, might be achieved by using comitative "with", as Lasersohn clearly shows.
Similar problems are discussed by Roberts C.(1990), where the distributive-group distinction is also viewed from the point of view of verb classes. The definition he gives is interesting and we report it below,
"The distributive reading may be triggered either by a quantificational determiner in the subject NP or by the presence of an explicit or implicit adverbial distributivity operator on the predicate. If a plural subject is nonquantificational (doesn't contain a quantificational determiner), we say that it is group denoting. A group reading arises when neither a group-denoting subject nor an adverbial element of its predicate contributes the quantificational force underlying distributivity."(ibid, 80).
In the following text, when dealing with a verb like "give" with a double object structure, Roberts notes how we are faced with fuzziness in case we want to specify the internal structure of an event, and there seems to be no fixed criteria to "denote an event", that makes it difficult to find a direct correlation between "truth conditions of such sentences and the number of events involved"(ibid.,81). Nonetheless we think it possible to divide up verbal predicates into classes denoting group/distributive readings, in lack of explicit quantified markers. These classes usually correspond to aspectual classes, as we already said above, with the exceptions of predicates containing lexical information as to their nature. Talking about this class of predicates R. mentions as inherently distributive predicates, "walk, eat, talk, know, own, have, be", which he assumes to be distributive since they are "related to personal identity of individual will"(ibid., 88) - however consider the case of "John and Mary own/have a beautiful car": in case they are married it can only be understood as group. Clearly R. is not personally in favour of indicating specifically the semantic nature of a given predicate "since it will follow from the sense of the predicate itself", in this case following Dowty(ibid., 94). However, we believe that lexical classification is required and may help to reach an automatic classification of situations. In trying to found a theory of the group/distributive distinction on the properties of predicates we surely do not forget to take into account the contribution of adverbial modifiers and quantifiers, as well as of generic interpretations. As R. comments(ibid., 94), in case we are dealing with states and actions (in our terms, activities and processes), we understand a distributive predication simply because they deal with one single individual at a time. Some predicates are only understandable with a group reading: for instance a predication about a team, or winning a rally race are all group predicates, and these might as well be encoded in the lexicon, contrary to what R. assumes, and thus derive directly from our knowledge of selectional restrictions on their use as in the case of simple predicates. In the same way we understand predicates like "disperse, walk together, be among" which require groups rather than individuals, and reciprocals which have also an additional number of semantic restrictions. Further on, we see that achievements and accomplishments with definite plural NP subjects, have a preferred group reading: they are "bring, carry, lift, leave, give, take, build". However, some have rather a distributive preferred reading: "ask, get up, wake up, vote". As we said above, they require some knowledge on what are the participants in the events.

7.1 Events and Participants Number

We might divide up utterances into two kinds, according to whether their subject is singular or plural; in addition, singular number might be overrun by quantified interpretation, in case we are dealing with a generic assertion. In order to decide whether we are in presence of a single event or multiple event, we then compositionally look for a second argument or participant in the event. In case there is none, we have a monadic predicate which receives its information directly from number specification: in a language like Italian, number might be only specified on verbal morphology and from there copied on to an empty pronominal subject. So in lack of information to the contrary, i.e. genericity or habituality, which could ensue from the presence of temporal adverbials, the event is interpreted as a "single_event" for singular number, or as a "multiple_event" for plural number, according to aspectual features - as we shall discuss below in more detail.

With monadic predicates, i.e. verbs belonging to syntactic classes inaccusative, inergative, ergative, passive, reflexives, reciprocals, inherent_reflexives, impersonal the event is interpreted as single or as multiple according to subject NP number: singular NP subject induce a single event reading, while plural NP subject do the opposite. The distributive-group dichotomy is easily solved in favour of the distributive reading - with the only exception of reciprocals, as can be shown by the following examples:

51a. John and Mary arrived at ten
   b. John and Mary run all morning
   c. The two boats sunk slowly / The two boys died yesterday
   d. The two boys have been killed intentionally
   e. The two houses have been built together
   f. John and Mary are staring at themselves in the mirror
   g. John and Mary are kissing each other
   h. John and Mary got angry at the birthday party
   i. John and Mary are easy to bribe

In case we add "together" at the end of each sentence we get different interpretations according to whether they are punctual or not: examples d. and h. might be understood as meaning a single "killing" event, or a single "getting angry" event. The reason lies in the fact that in both cases, the subject semantic role is interpreted as an Affected Theme and the focus is on the Change brought about by the existence of an unexpressed indefinite Agent implied by the event meaning and implicit in the lexical representation of the corresponding predicate argument structure. On the contrary, with ergative and inherent_reflexive (or inchoative) predicates, there is no Agent involved and we are focussing on the result_state itself and the introduction of "together" will contribute an interpretation by which the adverbial meaning quantifies over a spatial location, though lexically implied. Now consider a group quantification over the temporal location like "at the same time, contemporarily": only in the case of punctual predicates we get the right interpretation, which is also available with "together". The group interpretation is automatically produced in the case of the reciprocal g.

However, monadic predicates are only one possible type of predicates, and we can safely say that the great majority of verbal predicates are dyadic ones. In that case, determining the nature of the event requires control of each participants' number: in particular, we would like to state what is the relation existing between the two participants in the event, and the object NP with its semantic role are relevant in the determination of distributivity. As the following examples show, unless there is some special marker for cumulative or collective reading, plural Objects contribute a distributive event reading with predicates allowing quantification on time “tn”, belonging to achievement (with preparatory phase), accomplishment, activity and ingressive accomplishment classes:

52a. John killed three pigs this morning
   b. John reached the top of three mountains last summer
   c. John built/painted three houses last year
   d. John ate three sandwiches this morning
   e. John read three pages this morning/three newspapers this morning
   f. John washed three cups this morning
   g. John ran five times around the house

Plural objects contribute a collective reading with stative and with iterable achievements predicates:

53a. John loves three women
   b . John knocked twice at the door

Perceptual predicates are a subclass of stative predicates which however induce an ambiguous reading very much like result_states:

c. John saw three girls this morning/three flowers in his garden

d. John heard three sonatas this morning/three people talk in his neighbour's flat

Finally, they contribute an ambiguous reading with result_state achievements:

54a. John met three friends this morning

b. John noticed three Mayan books this morning/at Dillon's this morning

c. John lost three pencils this morning/three pencils in his office this morning

d. John found three pencils this morning/ three pencils in his pocket this morning

We use simple past tense which has a unifying import on the predicate event meaning; in case we used progressive and simple present, 9 and 10 remain the same, but 11 disambiguates its meanings according to factual conditions determined by our knowledge of the world. In any case, the result we get is to force the collective reading, where possible: notice that real punctual predicates like “find, see, notice” don’t allow internal views, i.e. progressive tense.

With dyadic predicates, this information is combined with the one deriving from the interpretation of the object NP and aspectual classes of the predicate. Consider now what happens when the object is a singular definite NP:

55a. Three bandits killed John this morning

b. Three climbers reached the top of the mountain last summer

c. Three friends woke John this morning

d. Three friends built that house last year

e. Three friends love that woman

With temporally bounded predicates, achievements (with preparatory phase) and accomplishment only one event is understood; in particular with accomplishment, the global view implies a collective reading of the “building of the house” event, even though the process of building itself might have been distributed among the three friends. The same applies to stative predicades: the loving event can only be interpreted collectively as a single identical state in which three friends found themselves.

On the contrary, ingressive accomplishments have a different preferred reading, even though they finally must be computed as one single event. In other words, we understand that: there is one single accomplishment - in turn, the house painted, the one sandwhich eaten, the one beer drunk, the one page read, the one cup washed - but also that the process has been partitioned, divided up among the three agents at different times:

56a. Three friends painted that house last year

b. Three friends ate one sandwich this morning

c. Three friends drank one beer this morning

d. Three friends read one page this morning/one newspaper this morning

e. Three friends washed one cup this morning

Finally, punctual achievements or result_states as we call them, induce distributive reading, in line with our representation that does not allow quantification internally b ut only globally:

57a. Three friends noticed that book this morning/at Dillon's this morning

b. Three friends lost that pencil this morning/in the office this morning

c. Three friends found that pencil this morning/in their pocket this morning

d. Three friends saw that girl this morning/that flower in the garden

e. Three friends heard the sonata this morning/the man talk in the neighbour's flat

As before, we comment on the possibility to interpret the examples in 12, 13 and 14 with progressive and simple present. The unit of time in the “now” induces collective readings for all predicates that allow these tenses. More examples could be made up with indefinite NPs: however, we take examples with indefinite NPs in subject position to be equivalent to the ones we already commented with a definite NP, simply because we tend to compute indefinite subject NPs as specific, but then for some classes of predicate the event may be quantified on. So we shall only present examples with indefinite NPs as OBJect.

58a. Three bandits killed a man this morning

b. Three climbers reached the top of a mountain last summer

c. Three boys saw a girl this morning/a flower in the garden

d. Three boys heard a sonata this morning/a man talk in the neighbour's flat

e. Three boys washed a cup this morning

f. Three boys met a man this morning

g. Three boys noticed a book this morning/a book at Dillon's this morning
h. Three friends painted/built a house last year
i. Three friends read a page this morning/a newspaper this morning

The previous examples have all ambiguous interpretations. However in the following example, related to stative, again we only get one possible meaning: they are all in the same loving state, with the same woman, at the same time, a necessarily collective interpretation:

59a. Three men love a woman

On the contrary, with result_states we get a distributive interpretation as preferred reading:

60a. Three friends ate a sandwich this morning
b. Three friends drank a beer this morning
c. Three men lost a pencil this morning/in the office this morning
d. Three men found a pencil this morning/in the pocket this morning

Also, notice that since the indefinite NP is not spatially linked, there is always a different reading available, due to the simultaneous happening of the event reported. Thus punctual and stative predicates are all distributionally readable with different individuals of the same class in different locations, though. The same reasonings can be made in case we change tenses from simple past to simple present and present progressive. In this case, the Quantized NP internal argument or OBJect interacts more closely with scoping of the plural cardinal NP "three men" overriding the static interpretation afforded by lexical representations.

Procedurally speaking, distributivity is added in the model as a function, which should be built up compositionally. Starting from the first argument, we may have the following encoding:

61a. "all" for plural/or mass NP with collective reading;
b. "many" for plural NP with distributive reading;
c. "one" for singular NP and for generic reading.

As a result we might end up with the following typology:

62a. distributive reading
1. many_to_one
2. many_to_all
3. one_to_many
4. many_to_many

b. collective reading
1. all_to_one
2. all_to_many
3. one_to_all
4. one_to_one
5. all_to_all

It is reasonable to assume at this point, that the interaction between our two parameters, Global and Internal, may be filtered by this mapping, and that the interpretation may result from the interaction with the proposals put forward above. The typology we created, represents a much finer-grained distinction of the mapping between participants and event which may be ascribed to quantificational properties of the external argument, the Subject, plus properties of the Object argument and may possibly be extended to properties of Indirect Object, Obliques and locative and temporal Adjuncts. Since these properties are already encoded and realize one kind of mapping, the interpretative process is much more straightforward.

8. Quantifier Raising

As we said at the beginning of chapter IV, quantifiers are assigned scope before entering the anaphoric binding module. In this way, NPs which fall under their scope may have received a quantified interpretation thus allowing for their number to be left unspecified. Consider as an example sentences like,

63a. The women who were carrying a baby each, dropped them.
b. Three women who were carrying a baby each, dropped them.
c. The women who were carrying a piano, dropped it.
d. A woman who wants to marry every man, doesn't have to disappoint them.

In these examples, as in donkey sentences, the antecedent of the pronoun *them/it* is contained within a restrictive relative clause, and is an indefinite NP *a baby* which is in the scope of the universal distributive quantifier *each* or itself a universally quantified NP, *every man*.

Two things should happen in a./b. in order for the indefinite NP to be taken as antecedent for the plural pronoun: the number of the indefinite NP should be neutralized to allow for anaphoric binding. Besides, whereas in b. cardinality of the babies is inherited from the quantifier which has scope over the indefinite NP, in case a. the cardinality of the indefinite NP should be entirely determined by contextual conditions in the discourse model. The same thing might have happened in case the antecedent were in a separate clause, subordinate or coordinate clause, or even a nonrestrictive relative clause. Remember that the net result of the binding module, is to prevent the pronoun to pop up at discourse level as a free external pronoun. In case the indefinite NP has distributive reading, it will be computed as a set; otherwise, a new individual will be asserted in the world. Finally in d., the quantified NP can bind the reference of the plural pronoun *them*.
Also definite NPs may be understood as being in the scope of some quantified expression: however, this might either be the result of external knowledge of the world in some case or the presence of a possessive:
64a. Every husband loves his wife
b. Every/each man left the bar at ten
c. Every man wants to buy the car of his dreams
As may be easily noted, both in a. and c. the definite NP may be understood as quantified owing to the fact that the universally quantified NP has scope over it and there is a possessive pronoun bound to it. On the contrary, in b. we might surmise that there is only one bar and the men left it all at the same time. At f-structure level, this fact can only be explained in case we take grammatical functions as carrier of structural information. In all examples, the dominance relation is determined by the presence of a SUBJect quantified NP and an OBJect definite NP. In addition, in a. we have a case of generic assertion; in b. on the contrary, a specific spatiotemporal location anchors the main relation and its arguments; finally, in c. an intensional predicate "want" makes the reading of the main relation "buy" opaque and devoids it of a specific anchoring, as was the case with 1d. above. Other cases of definite NPs with quantified reading in specific spatiotemporal locations may be given by the following example,
65. The two little pigs went back each to its own little house./I due porcellini ritornarono ciascuno alla propria casetta.
Given the fact that anaphoric binding should capitalize on the results of the module for quantifier scope assignment, we compute quantifier raising before anaphoric binding and after syntactic binding. The algorithm for quantifier raising operates on f-structures and proceeds as follows:
a. quantified NPs are individuated from the content of their Spec: the "quant" attribute should be present and filled with some value;
b. a q-marker or quantified variable is added at f-structure level;
c. the quantifier/s is/are raised by a recursive procedure which stops at the first q-barrier:
a q-barrier is simply the propositional level in which the quantifier is construed. A q-operator is added at this level in a list which has q_ops as functional attribute;
d. the same applies to indefinite NPs, which are locally disambiguated: not every indefinite NP can be treated as a quantifier;
e. when we come to definite NPs, these are computed as indefinite quantified NPs in case a number of conditions are met, as specified above;
f. finally, we might end up with a list of q-operators which has more than one member: at this point we only want to swap their linear order in case the quantifying force of the first q-operator is less than the force of the second, and so on. This is what is done by the predicate "solve_same_level_scope";
g. in the remaining cases we take the quantifier which is higher at f-structure or it has been assigned the hierarchically higher grammatical function - where SUBJect is the highest - to assume scope of the remaining q-operators. The result is marked at f-structure level with the attribute-value pair "interpretation:quantified".

The same procedure applies to wh- words in case they appear in the same proposition where a quantified NP is present: they behave like indefinite NPs. The well-known subject-object asymmetry applies to both types of elements(see Delmonte, 1990), as shown by the following examples:
66a. Who bought everything for the party?
b. What did everybody buy for the party?

where the universal quantifier may assume higher scope than the wh- word in case they are both contained within the same proposition and the wh- word is not in a chain with a SUBJect. As we said, we simply compute wh- binding and establish a syntactic chain by coindexing: in this way we do not need to go through reconstruction of the wh- element into the extraction place. These are the main predicates of the quantifier scope algorithm:

```
A. quantifiers_raising :-
    quantified_np(QDescs),
   add_qmarks(QDescs, NewQDescs),
   raise_quantifiers(NewQDescs),
   indefinite_np(IndefDescs),
   add_qmarks(IndefDescs, NewIndefDescs),
   raise_indefinites(NewIndefDescs),
   definite_np(IndefDescs),
   add_qmarks(IndefDescs, NewIndefDescs),
   raise_definites(NewIndefDescs),
   solve_same_level_scope,
   mark_quantified_interpretation.

B. raise_quantifiers([q(_, _, Node, Type, Qmark) | QDescs]) :-
     raise_quantifier(Node, Type, Qmark),
     !,
     raise_quantifiers(QDescs).
   raise_quantifiers([]).

C. raise_quantifier(Node, Type, Qmark) :-
     node(NodeTo)::_::node(Node),
     ( q_barrier(Type, NodeTo)
     ->
     add_qop(NodeTo, Qmark, Type)
     ;
     raise_quantifier(NodeTo, Type, Qmark) ).
```

Here below we show the output of the parser on a typical example of donkey sentences, where a universal quantifier takes scope over an indefinite NP and arbitrary reading is produced: this can be read out at propositional level, where the attribute perf(ormative) is present:

67. [every farmer who owns a donkey beats it]

```
perf:generic
index:f6
pred:beat
lex_form:[np/subj/agent/[human], np/obj/theme_aff/[human, animate]]
mood:ind
tense:pres
cat:activity
subj/agent:index:sn2
         cat:[human]
         pred:farmer:[gen:mas,num:sing,pers:3]
         spec:def:'0':[part:-,quant:every]
         interpretation:arbitrary
         mods:mod/predic:topic:topic_type:relative
                         index:sn5
                         cat:[human]
                         pred:who:[gen:mas,num:sing,pers:3,case:nom]
                         controller:sn2
                         tab_ref:[+ ref, + pro, + ana, - me]
                  perf:generic
                      index:f5
                      pred:own
                      lex_form:[np/subj/owner/[human],
np/obj/actor/[human,animate,object]]
                      mood:ind
                      tense:pres
```

```
                    cat:state
                    subj/owner:index:sn24
                              cat:[human]
                              pred:pro:[gen:mas,num:sing,pers:3,case:nom]
                              spec:def:+
                              controller:sn5
                              tab_ref:[+ ref, + pro, - ana, - me]
                    obj/actor:index:sn26
                           cat:[animate]
                           pred:donkey:[gen:neut,num:sing,pers:3]
                           spec:def:-
                           subj/nil:index:sn29
                                 pred:vbl
                                 controller:sn24
                                 tab_ref:[+ ref, - pro, - ana, - me]
                           tab_ref:[+ ref, - pro, - ana, + class]
                           qmark:q2
                           interpretation:quantified
                    aspect:state
                    rel1:[td(f5_es06)=tr(f5_es06)]
                    rel2:[included(tr(f5_es06), tes(f5_es06))]
                    specificity:-
                    ref_int:[tr(f5_es06)]
                    qops:[q2]
          tab_ref:[+ ref, - pro, - ana, + class]
          qmark:q1
obj/theme_aff:index:sn35
          cat:[object, animate]
          pred:it:[gen:neut,num:sing,pers:3,case:acc]
          spec:def:+
          tab_ref:[+ ref, + pro, + ana, + me]
          antecedent:sn26
aspect:activity
rel1:[td(f6_es06)=tr(f6_es06)]
rel2:[included(tr(f6_es06), tes(f6_es06))]
specificity:-
ref_int:[tr(f6_es06)]
qops:[q1]
```

As we said, at first QR applies adding q-markers q1 and q2, locally for each quantified f-structure; then an operator is raised accordingly at propositional level; finally, quantifier scope is executed and a functional annotation is added where required. In our case, the f-structure where the indefinite NP "a donkey" is described receives the annotation, interpretation:quantified. Then, anaphoric binding is computed and pronouns are coindexed with their possible antecedents: in our case, the pronoun "it" is coindexed with the NP "a donkey" contained in the relative clause. F-command is suspended in this case and the relative portion of f-structure is made visible to the binding algorithm by a specific call. Finally, the algorithm for arbitrary interpretation is called and functional annotations are added both at NP level and at propositional level with the attribute-value pair perf:generic. These annotations are used by the model as well as by the interpretation to compute adequate representations for the situations described by the utterance. In particular, as discussed at length here below, arbitrary readings arise owing to tense and aspect specifications and will produce - in case it is lacking - a quantification over events or states, so that we can understand that a given event/state will hold at any temporal location, assuming a specific anchoring for spatial locations, as will be discussed below. In turn, an arbitrary reading for an NP amounts to computing a quantified NP where we are dealing with a "class" rather than with sets of or singleton individuals - in other words, reference in the world is suspended and there is no specific set or group of people we are referring to. Though, since we describe classes as infons, we always intend them to be classes of individuals or entities related to some spatiotemporal coordinate, and not universally valid. In addition, a generic assertion is usually the subjective statement of some individual or other, and is computed from a given perspective, as will be commented here below.

8.1 Uniqueness and Genericity

As to the number of remaining problems, we subscribe to what R. says about determiners and distributivity: in other words, it seems possible to classify NPs according to the nature of their determiners. In this way, compositionality should be preserved when computing semantic interpretation. Coming now to the problem of "uniqueness" raised and discussed among others in Heim(1990) and Kadmon(1990), this is treated in our model as follows:

vi. we split the problem of characterizing indefinites into two parts: the description of the individual and the function applying over the relation in which that individual is involved. As to the description of the individual, in case it is an indefinite quantified over by some operator, be it an "if" modal operator, or another NP, quantified or quantifier itself, the system computes at first an "entity" description with a class restriction in the form of infon, i.e. a sit with a polarity and spatiotemporal location indices; this entity might become an individual or a set in the following text in case some pieces of information are made available about that individual.

Note that this treatment is not available for indefinite NPs contained in generic assertions: in this case the interpretation is straightforward. Let's take example 67. above, which we report here below,

68. Every farmer who owns a donkey beats it.

the meaning we want to get is approximately the following,

there is an indefinite set of farmers and an indefinite set of donkeys which are however contextually bound by spatiotemporal indices - indefinite sets are described by the attribute "class" in our model which have as cardinality the value of the quantifier associated to the "card" attribute;

there is a one-to-one function that applies on the owing relation and the beating relation requiring its arguments to be thus distributed;

there is a quantification over events which is the unexpressed "always" that quantifies over the spatio-temporal locations of the event described by the main situation; the owing event is computed as being implied by the main situation. This might be an overgeneralization: in fact, the spatial location might be simply inherited from the previous text and thus equated with the one computed for the subject uttering the generic assertion, since we always want utterances to be associated to a perspective or other. In that case, the index corresponding to the spatial location would be filled rather than corresponding to nil. As to temporal locations, its event/state time is the location whose reference time which might be included in some more comprehensive main location inherited from the previous portion of text. Suppose now that we are in 1950, in Boston, and these are the actual main locations, this might be the description of the utterance in the model as produced by our system:

```
loc(infon1, id1, [arg:main_tloc, arg:1950)
loc(infon2, id2, [arg:main_sloc, arg:boston)
fun(id9, one_to_one, [arg:id3, arg:id4], 1, id1, id2)
quant(id9, always, [main_tloc:id1, main_sloc:id2], 1)
sit(id9, imply, [arg:id7, arg:id5], 1, id1, id2)
class(infon1, id3)
card(infon2, id3, every)
sit(infon3, isa, [ind:id3, class:farmer, 1,  id1, id2)
sit(infon4, isa, [ind:id3, class:man], 1,  id1, id2)
class(infon5, id4)
card(infon6, id4, some)
sit(infon7, isa, [ind:id4, class:donkey], 1,  id1, id2)
sit(infon8, isa, [ind:id4, class:animal], 1,  id1, id2)
sit(id5, own, [owner:id3, actor:id4], 1, tes(f5_aa1), id2)
sit(infon13, isa, [arg:id5, arg:ev], 1, tes(f5_aa1), id2)
sit(infon14, isa, [arg:id6, arg:tloc], 1, tes(f5_aa1), id2)
sit(infon16, time, [arg:id5, arg:id6], 1, tes(f5_aa1), id2)
sit(id7, beat, [agent:id3, theme_aff:id4], 1, tes(f6_aa1), id2)
sit(infon17, isa, [arg:id7, arg:ev], 1, tes(f6_aa1), id2)
sit(infon18, isa, [arg:id8, arg:tloc], 1, tes(f6_aa1), id2)
sit(infon20, time, [arg:id7, arg:id8], 1, tes(f6_aa1), id2)
included(tr(f6_aa1), id1)
```

9. The algorithm for temporal interpretation

In our model all entities and relations are assigned a spatiotemporal location which is made up of two indices: one index is bound to the main temporal location in the case of individuals. As to relations and modifiers of the main relation, the index for the time location is derived from the event/state time, i.e. TES. In turn, this index is in a given logical relation with the TR(Reference Time) of the previous text span, which is related to the discourse focus TF: it may be BEFORE, AFTER, MEETS, OVERLAP etc. with it. The reference of the current TR is furthermore asserted to be included in some main temporal location which could be present in the previous text span. Thus, individuals receive directly a time index which bind their existence in the world and their properties, such as roles, or attributes, to some main temporal location; in case of names associated to individuals, we assign them to a universal location, in other words, we assume that in the domain specified by the text that name is used unambiguously to refer to a single well defined individual. This bipartition is quite natural: entities such as individuals or sets are assumed to be in a given time location for a longer stretch than the actual relation in which they are currently involved. The latter might be a punctual event, thus having a very short duration in time. Event properties are thus different from entities properties as to their temporal location. As we shall see in this chapter, event properties are basically derived from the aspectual classification associate to the predicate, and only partly from the semantic role associated to the arguments of the predicate.

Temporal interpretation is computed compositionally from the local features associated to the verb tense and the static lexical label associated to aspect, plus a number of relevant information like definiteness of the subject NP, and of the Object NP, plus their number. These features contribute to assigning a first dynamic aspectual label to the sentence in which the verbal predicate is analysed. This allows the system to compute local temporal relation intersententially, taking into adequate account all the elements which contribute to the definition of temporal relations; these elements are essentially taken from Reichenbach's proposal. This computation is added to the f-structure of each clause, where it will have to face the complexity arising from the presence of subordinate, coordinate and complement clauses. Finally, the result of the utterance temporal computation is passed on to the discourse module for temporal reasoning which is based on Allen's proposal. At this level, temporal intervals are generated and are attached at nodes in a cluster. The logical notation introduced by Allen is perspicuous enough to allow for the overall representation of discourse structure, where reference intervals are generated by taking into account local logical relations.

The following is a text adapted from Webber(1988), where we see that the second utterance expresses an activity which is presumably ended by the time Mario arrives: in this case, we want the system to understand the relationship intervening between someone waiting for somebody else which has now arrived, a FINISHED-BY relation, which is computed by means of semantic control. A more generic temporal logical relation would be CONTAIN, where the "waiting" time interval CONTAINS the "running home" event.

24a. Mario ieri corse a casa/Yesterday Mario ran home
  b. Maria lo aspettava/Maria was waiting for him
  c. Lei lo insultò/She insulted him

Wer shall follow the output of each linguistic module of the system starting from the syntactic and functional representation. These are the three f-structure representations which are built up on the basis of c-structure:

```
Rete ta - [mario ieri corse a casa]
indice:f4
pred:correre
lex_form:[sn/sogg/agente/[umano], sp/obl/locativo/[da,in,a]/[luogo]]
modo:ind
tempo:pass_rem
cat:cambiamento
sogg/agente:indice:sn2
        cat:[umano]
        pred:mario
        gen:mas
        num:sing
        spec:def:'0'
```

tab_ref:[+ ref, - pro, - ana, - class]
obl/locativo:indice:sn28
cat:[oggetto, luogo]
pred:casa
gen:fem
num:sing
spec:def:'0'
tab_ref:[+ ref, - pro, - ana, + class]
adjs:avv:pred_avv:ieri
tipo:deittico
duraz:non_punt
config:[tr<td]
aspetto:accomp
rel1:[tr(f4_ta)<td(f4_ta)]
rel2:[tr(f4_ta)=tes(f4_ta)]
definitezza:+
ref_int:[tr(f4_ta)]

Rete tb - [maria lo aspettava]
indice:f4
pred:aspettare
lex_form:[sn/sogg/actor/[umano], sn/ogg/tema_nonaff/[umano]]
modo:ind
tempo:imp
cat:attivita
sogg/actor:indice:sn2
cat:[umano]
pred:maria
gen:fem
num:sing
spec:def:'0'
tab_ref:[+ ref, - pro, - ana, - class]
ogg/tema_nonaff:indice:sn3
cat:[umano]
pred:lo
pers:3
gen:mas
num:sing
caso:[acc]
spec:def:+
tab_ref:[+ ref, + pro, + ana, + me]
antecedente:esterno
interpretazione:definita
aspetto:attivita
rel1:[tr(f4_tb)<td(f4_tb)]
rel2:[incluso(tr(f4_tb), tes(f4_tb))]
definitezza:+
ref_int:[tr(f4_tb)]

Rete td - [lei lo insultò]
indice:f4
pred:insultare
lex_form:[sn/sogg/agente/[umano], sn/ogg/tema_aff/[umano]]
modo:ind
tempo:pass_rem
cat:risultato
sogg/agente:indice:sn1
cat:[umano]
pred:lei
pers:3
gen:fem
num:sing
spec:def:+
tab_ref:[+ ref, + pro, - ana, + me]
antecedente:esterno
interpretazione:definita
ogg/tema_aff:indice:sn2
cat:[umano]
pred:lo

```
        pers:3
        gen:mas
        num:sing
        caso:[acc]
        spec:def:+
        tab_ref:[+ ref, + pro, + ana, + me]
        antecedente:esterno
        interpretazione:definita
aspetto:achiev_tr
rel1:[tr(f4_td)<td(f4_td)]
rel2:[tr(f4_td)=tes(f4_td)]
definitezza:+
ref_int:[tr(f4_td)]
```

9.1 Tense and Aspect: two separate relations with Time Reference

We shall now concentrate on f-structures representing temporal interpretation at sentence level. The algorithm for temporal interpretation is called in order to compute the role of arguments, adverbs and other adjuncts. These are accessed in order to establish whether some additional interpretation is available. We use the tripartite Reichenbachian structure made up of TR=reference time, TD=speech time, and TES=event/state time, which may be equivalent, may be included into one another, may precede or follow one another.
The computation is worked out into two separate relations, Rel1, and Rel2: Rel1 works according to tense information, Rel2 according to aspectual information. At first we compute Rel1 by matching mood and tense information in a table loookup as follows,

```
calc1(F,pres,td(F)=tr(F)).
calc1(F,pres_progr,td(F)=tr(F)).
calc1(F,pass_pross,tr(F)<td(F)).
calc1(F,imperfect,tr(F)<td(F)).
calc1(F,imp_progr,tr(F)<td(F)).
calc1(F,trap_pross,tr(F)<td(F)).
calc1(F,pass_rem,tr(F)<td(F)).
calc1(F,past,tr(F)<td(F)).
calc1(F,past_perf,tr(F)<td(F)).
calc1(F,perf,tr(F)≤td(F)).
calc1(F,trap_rem,tr(F)<td(F)).
calc1(F,future,td(F)<tr(F)).
calc1(F,fut_progr,td(F)<tr(F)).
calc1(F,fut_ant,td(F)<tr(F)).
```

where we see the Italian and the English set of tenses: pass_pross translates sometimes the English Perfect and sometimes the Simple Past; "imperfetto" has no English correspondence; we have Present Perfect and Past Perfect with their actual English value; pass_rem translates Past Tense; fut_ant translates future in the past. This Relation is passed on to "calc2" which computes Rel2 taking aspect into account. Then temporal modifiers are accessed and some further changes may take place. As can be seen from the following table, Progressive tense together with aspect set on Achievements contributes an interpretation "prec_imm", i.e. precedes immediately:

```
calc2(F,pres_progr,achiev_tr,event,_,prec_imm(tr(F),tes(F))).
calc2(F,imp_progr,achiev_tr,event,_,prec_imm(tr(F),tes(F))).
calc2(F,pres,_,td(F)=tr(F),included(tr(F),tes(F))).
calc2(F,pres_progr,event,_,included(tr(F),tes(F))).
calc2(F,pass_pross,_,tr(F)<td(F),tr(F)=tes(F)).
calc2(F,imp,_,_,included(tr(F),tes(F))).
calc2(F,imp_progr,event,_,included(tr(F),tes(F))).
calc2(F,trap_pross,_,_,tes(F)<tr(F)).
calc2(F,pass_rem,_,_,tr(F)=tes(F)).
calc2(F,future,_,_,tr(F)=tes(F)).
calc2(F,future,state,_,included(tr(F),tes(F))).
calc2(F,fut_progr,event,_,included(tr(F),tes(F))).
calc2(F,fut_ant,_,_,tes(F)<tr(F)).
```

Adverbs or adjuncts may specify the internal structure of temporal location, and this information be explicitly stated in the final output. In our parser, temporal adverbs are lexically assigned a configuration, a type and a duration if any: these parameters are passed to the routine that interprets Rel1 and Rel2. There are two main calls to adverbs and temporal adjuncts: one is just a table lookup which taps directly lexical information; the other one computes the contents of the adverbial phrase or prepositional phrase first, and then passes this information to a table lookup.

```
adverb(F,Type,Config,Durat,Rel1x,Rel2x,Rel1,Rel2):-
        tab_adv(Type,Config,Durat,Rel1x,Rel2x,Rel1,Rel2).
adverb(F,Head,Type,Duration,RelAdv).

adverb(F,Head,deictic,punct,tr(F)=Head).
adverb(F,Head,deictic,non_punct,included(tr(F),Head)).
adverb(F,Head,clock_cal,punct,tr(F)=Head).
adverb(F,Head,clock_cal,non_punct,included(tr(F),Head)).
adverb(F,Head,duration,non_punct,durat(tr(F),Head)).
adverb(F,Head,temporal,non_punct,durat(tr(F),Head)).
adverb(F,Head,frequency,iterate,iterate(te(F),Head)).
adverb(F,Head,frequency,intervalled,intervalled(te(F),Head)).

tab_adv(deictic,[td<tr],_,td(F)<tr(F),tes(F)<tr(F),td(F)<tr(F),included(tes(F),tr(F))).
tab_adv(deictic,[td=tr],non_punct,tr(F)<td(F),tes(F)<tr(F),tr(F)<td(F),tr(F)=tes(F)).
tab_adv(temporal,[td=tr],non_punct,td(F)=tr(F),tes(F)<tr(F),tr(F)<td(F),tr(F)=tes(F)).
tab_adv(clock_cal,[tr<td],_,tr(F)<td(F),Rel2,tr(F)<td(F),Rel2).
```

More or less the same procedure is used to compute the overlapping of tenses in sentential complements and subordinate clauses, which however in addition have a semantic marker as subordinator. The Rels of two sentences at first are computed separately and then together, where "reltr" and "reltes" attributes appear. The subordinate clause is a transformative achievement and has a TR = reference time which is included in the TD = discourse time and is equal to the TES = event/state time. In the case of the main clause, we have an activity where the TD is included in the TR and the TES includes the TR. It is temporally specific and has as referential interval the label f4_sub2. The comparison of the two separate clauses gives as a result the following: the TR relation is expressed as an equality between the two - main and subordinate - TRs. In turn the TES are in an inclusion relation, the subordinate TES being included in the main one.
Consider now a simple example, [mario telefonò a luigi perché voleva delle informazioni]/Mario called Luigi because he wanted some piece of information

```
26.aspect:state
            rel1:[tr(f8_sub1)<td(f8_sub1)]
            rel2:[included(tr(f8_sub1), tes(f8_sub1))]
            specificity:+
            reltr:[tr(f4_sub1)=tr(f8_sub1)]
            reltes:[included(tes(f4_sub1), tes(f8_sub1))]
aspect:activity
rel1:[tr(f4_sub1)<td(f4_sub1)]
rel2:[tr(f4_sub1)=tes(f4_sub1)]
specificity:+
ref_int:[td(f4_sub1)]
```

As can be easily understood from the representations, the information now available is that the subordinate is a state and the main clause is an activity and the relations intervening between the two are now different: in particular the two TRs are now in an equality relationship. This computation allows the semantic module to assign spatio-temporal locations to participants in an event/state. More examples can be studied, and we think it important to give a sequence of utterances which can then be analysed in discourse by means of Allen's module.
Going back to our three sentences making up our text, the following temporal computations are taken from the f-structures included above:

```
a. adjs:adv:pred_adv:yesterday
     type:deictic
     durat:non_punct
```

```
      config:[tr<td]
   aspect:accomp
   rel1:[tr(f4_ta)<td(f4_ta)]
   rel2:[tr(f4_ta)=tes(f4_ta)]
   specificity:+
   ref_int:[tr(f4_ta)]

b. aspect:activity
   rel1:[tr(f4_tb)<td(f4_tb)]
   rel2:[included(tr(f4_tb), tes(f4_tb))]
   specificity:+
   ref_int:[tr(f4_tb)]

c. aspect:achiev_tr
   rel1:[tr(f4_td)<td(f4_td)]
   rel2:[tr(f4_td)=tes(f4_td)]
   specificity:+
   ref_int:[tr(f4_td)]
```

In a. we have a temporal main location(MTL), "yesterday", which is assumed as encompassing the main temporal streamline of narration: in turn, tense moves reference times TR of each main proposition forward and backward on this streamline, until a new MTL is asserted in the narration.
In a. we have the information that the TR precedes the TD and that it coincides with the TES; in addition we know that it is "specific", hence not generic, and that a given time interval is assigned a given label. In b. TR always precedes TD but this time it includes the TES. Finally, in c. we know that the TR precedes the TD as before but there is coincidence between the TR and the TES.
These information are then passed on at text level to the further level of computation which is explained below.

9.2 Implementing Allen's algorithm

In Allen's paper(1983) an interval-based temporal logic is introduced, together with a computationally effective reasoning algorithm. The temporal representation takes the notion of temporal interval as primitive; a notion of reference intervals is also introduced which is used to control the amount of deduction performed automatically by the system. By using reference intervals, the amount of computation involved when adding a fact in the temporal knowledge base can be controlled in a predictable manner, comments the author(ibid.,833). In our algorithm we also use Allen's explicit notation to express all the possible relations that can hold between two intervals by means of 13 relations.
Our implementation of Allen's algorithm takes as input Reichenbach's relations as they are independently computed at f-structure level. However, one of the main component's of the overall computation is the relation intervening between Time Focus and the Time Reference of the current utterance. Time Focus is a notion introduced by Webber(1985) which captures temporal information relevant for discourse and text analysis: it can be viewed as a stack which has on top the TR on which the discourse is currently focussing for any given utterance. The main call of our version of Allen's algorithm is the following,

```
anaphor_temp(SNo, Asp, S_id,tr(S_id)<td(S_id),tr(S_id)=tes(S_id))
  :-
  one time_focus(_, tes(TF_id)),
  !, Asp\=state,
  allen_1(S_id,tr(S_id)),
  relation(tr(TF_id),tes(TF_id),R1),
  constraints([bf],R1,R),
  create_interval(tr(TF_id),tr(S_id)),
  add_rel(tr(TF_id),tr(S_id),R),
  asserta(time_focus(NoFr, tes(S_id))),

anaphor_temp(SNo, Asp, S_id,tr(S_id)<td(S_id),tr(S_id)=tes(S_id))
  :-
  one time_focus(_, tes(TF_id)),
```

```
!, Asp=state,
allen_1(S_id,tr(S_id)),
relation(tr(TF_id),tes(TF_id),R1),
constraints([dr],R1,R),
create_interval(tr(TF_id),tr(S_id)),
add_rel(tr(TF_id),tr(S_id),R).
```

It instantiates the current TF on top of the stack and determines the relation intervening between the TF and the TR of the current utterance. Subsequently, it determines the relation intervening between the TRs and it is asserted in the graph or cluster of relations and TRs computed so far. In order to do this, constraints are checked on whether two adjacent nodes may be included or not in the same Reference Interval. Finally the TF is updated if necessary. The following is the main call for utterances in which the TR precedes the TD, and equals the TES. We have sentence number and identifier, aspect and the relations inherited from f-structure. We recover the TF and we check that aspect be different from State: for temporal representation with a State aspect the call is the following one, where TF is not updated. The call to allen_1 looks for temporal relations of sentences which have that TR as Reference Interval in the graph and memorizes them. The new intervals created have the current TR as reference interval.
The call to Relation looks for comparable nodes and then for a "direct" or "indirect" connection between TR and the TES in the sentence which has fixed the TF,

```
relation(I,J,R) :-
   comparable(I,J),
   direct_relation(I,J,R),
   !.
```

Finally, it tries an intersection with the set of 13 logical relations and then passes the output to the following call on Constraints, which however has already a logical relation as internal constraint; then, the algorithm looks at a transitivity table for each pair of labels and returns the union of all the answers.

```
indirect_relation(I,J,R) :-
     bagof(Rel,path_rel(I,J,Rel),ListRel),
     rix(ListRel,R).
path_rel(I,J,R) :- go_to(J,I,Path),
              constraints_along_path(Path,R).
```

We then take the intersection of these constraints with the previously known constraint, very much in the line of what Allen suggests (ibid.,837). In this way, we are ready to add_rel, or to add a new relation to the network which has the current TR as time reference. In this way a Reference Interval is created with all relations which fall along the path. Finally we assert the current TES as new TF.

```
add_rel(I,J,R) :-
 subset(R,[bf,af,dr,cn,ov,ob,me,mb,st,sb,fn,fb,eq]),
 !, (direct_relation(I,J,N),
  !, intersection(R,N,X),
   (subset(X,N),
    !, write_rel(I,J,X),
    assertz(todo(I,J)),
    update
  ;
  write_rel(I,J,R),
  assertz(todo(I,J)),
  update).
```

9.3 Semantic representation

The example might be consider an exceptional case: there is a past progressive (in Italian "imperfetto") which has to be computed as FINISHED-BY relation with the previous discourse segment. As we said, this requires semantic control to be activated. By semantic control we mean a linguistically based strategy which checks whether the same individual associated with identifier Id1 is a participant of an accomplishment, i.e. is an Agent in the previous portion of text, and is an Unaffected Theme in the

current utterance which represents an Activity. This is what actually takes place in the text. Here below we follow Allen's computation at text level:
27. Mario ieri corse a casa/Yesterday Mario ran home
rel_temp(infon6, td, tr(f4_ta), [af])
rel_temp(infon7, tes(f4_ta), tr(f4_ta), [eq])
ref_interval(tr(f4_ta))
time_focus(1, tes(f4_ta))
loc(infon3, id1, [arg:main_tloc, arg:ieri])
included(tr(f4_ta), id1)

We have only two temporal relations, a time focus, and a reference interval; in the model a temporal main location which in this case is represented by the deictic "yesterday". Besides adverbials, we can have any kind of temporal adjunct in the form of a PP. The inclusion relation is expressed every time there is a deictic main location which the reference time of the current event/states may be anchored at. From temporal relations we also know that this reference time is situated before the TD or speech time and that is equal to the event/state time. Finally, from the full semantic representation produced by the model we also know that the actual time is in the past.
28. Maria lo aspettava/Maria was waiting for him
rel_temp(infon20, td, tr(f4_tb), [af])
rel_temp(infon22, tr(f4_ta), tr(f4_tb), [eq])
rel_temp(infon23, tes(f4_ta), tr(f4_tb), [eq])
rel_temp(infon26, tes(f4_ta), tes(f4_tb), [fn])
rel_temp(infon27, tes(f4_tb), tr(f4_ta), [fb])
rel_temp(infon28, tes(f4_tb), tr(f4_tb), [fb])
ref_interval(tr(f4_tb))
finished_by(tes(f4_ta),tes(f4_tb))

In utterance 2 we still know that reference time is situated in the past, and that the two reference times of the current and the previous utterance coincide, but also that there is a finishing relation between the two. There is also a new reference interval which is however abandoned in the following utterance. No new time focus is produced. When we get to utterance no.3 we notice that temporal relations are entertained only with utterance no.1 to which the insulting event is actually connected and not to waiting event expressed in the closely adjacent clause. We also have a new time focus which is the event/state time of the current utterance.
29 Lei lo insultò/She insulted him
rel_temp(infon38, td, tr(f4_td), [af])
rel_temp(infon39, tes(f4_td), tr(f4_td), [eq])
rel_temp(infon40, tr(f4_ta), tr(f4_td), [bf])
rel_temp(infon41, tes(f4_td), tr(f4_ta), [af])
time_focus(3, tes(f4_td))
ref_interval(tr(f4_ta), tr(f4_td))
included(tes(f4_td), id1)

However, in order to generate that temporal interpretation we need a Discourse Model which allows us to realize coreference. In turn coreference is triggered by the Topic Hierarchy, where all referential expressions are evaluated and weighted. Semantic interpretation is activated in Information Structure where factuality, temporal focus and other semantic elements are computed. The Discourse Model builds up the list of Entities of the World by inheritance; in turn these information are used to construct Discourse Structure and Relations. Here below we include the output of each module starting from Topic Hierarchy.

TOPIC HIERARCHY

ta.obj- [mario ieri corse a casa]
WEIGHTED LIST OF TOPICS :
ref_ex(sn2, mario, [+ ref, 0def, nil, nil, - pro, - ana, - class], nil, mas, sing, [umano], sogg/agente)/ -10
ref_ex(sn28, casa, [+ ref, 0def, nil, nil, - pro, - ana, + class], nil, fem, sing, [oggetto, luogo], obl/locativo)/28

EXPECTED TOPIC : ref_ex(sn2, mario, _, nil, mas, sing, [umano], sogg/agente)

POTENTIAL TOPICS : ref_ex(sn28, casa, [+ ref, 0def, nil, nil, - pro, - ana, + class], nil, fem, sing, [oggetto, luogo], obl/locativo)
stato(1, cambia)

tb.obj - [maria lo aspettava]
WEIGHTED LIST OF TOPICS :
ref_ex(sn3, lo, [+ ref, + def, nil, nil, + pro, + ana, + me], 3, mas, sing, [umano], ogg/tema_nonaff)/ -15
ref_ex(sn2, maria, [+ ref, 0def, nil, nil, - pro, - ana, - class], nil, fem, sing, [umano], sogg/actor)/ -9

MAIN TOPIC : ref_ex(sn3, mario, _, 3, mas, sing, [umano], ogg/tema_nonaff)
SECONDARY TOPIC : ref_ex(sn2, maria, _, nil, fem, sing, [umano], sogg/actor)
stato(2, continua)

td.obj - [lei lo insultò]
WEIGHTED LIST OF TOPICS :
ref_ex(sn1, lei, [+ ref, + def, nil, nil, + pro, - ana, + me], 3, fem, sing, [umano], sogg/agente)/ -20
ref_ex(sn2, lo, [+ ref, + def, nil, nil, + pro, + ana, + me], 3, mas, sing, [umano], ogg/tema_aff)/ -15

MAIN TOPIC : ref_ex(sn1, maria, _, 3, fem, sing, [umano], sogg/agente)
SECONDARY TOPIC : ref_ex(sn2, mario, _, 3, mas, sing, [umano], ogg/tema_aff)
stato(3, retaining)

INFORMATION STRUCTURE

ta.obj - [mario ieri corse a casa]
CLAUSE IDENTIFIER: 1-n1
CLAUSE TYPE: main/prop
FACTUALITY: factive
CHANGE IN THE WORLD: culminated
RELEVANCE: foreground
TEMPORAL RELATION: overlap(tes(f4_ta), td(f4_ta))
DISCOURSE FOCUS: tes(f4_ta)
DISCOURSE RELATION: narration
DISCOURSE DOMAIN: objective
SUBJECT OF CONSCIOUSNESS: none

tb.obj - [maria lo aspettava]
CLAUSE IDENTIFIER: 2-n1
CLAUSE TYPE: main/prop
FACTUALITY: factive
CHANGE IN THE WORLD: gradual
RELEVANCE: foreground
TEMPORAL RELATION: finished_by(tes(f4_tb), tes(f4_ta))
DISCOURSE FOCUS: tes(f4_ta)
DISCOURSE RELATION: elaboration
DISCOURSE DOMAIN: objective
SUBJECT OF CONSCIOUSNESS: none

td.obj - [lei lo insultò]
CLAUSE IDENTIFIER: 3-n1
CLAUSE TYPE: main/prop
FACTUALITY: factive
CHANGE IN THE WORLD: culminated
RELEVANCE: foreground
TEMPORAL RELATION: after(tes(f4_td), tes(f4_ta))
DISCOURSE FOCUS: tes(f4_td)
DISCOURSE RELATION: narration
DISCOURSE DOMAIN: objective
SUBJECT OF CONSCIOUSNESS: none

DISCOURSE MODEL

ta.obj - [mario ieri corse a casa]
loc(infon3, id1, [arg:main_tloc, arg:ieri])
loc(infon4, id2, [arg:main_sloc, arg:casa])
ind(infon5, id3)
fact(infon6, inst_of, [ind:id3, class:uomo], 1, univ, univ)
fact(infon7, name, [mario, id3], 1, univ, univ)
fact(infon9, isa, [arg:id2, arg:casa], 1, id1, id2)

fact(id4, correre, [agente:id3, locativo:id2], 1, tes(f4_ta), id2)
fact(infon10, isa, [arg:id4, arg:ev], 1, tes(f4_ta), id2)
fact(infon11, isa, [arg:id5, arg:tloc], 1, tes(f4_ta), id2)
fact(infon12, pass_rem, [arg:id5], 1, tes(f4_ta), id2)
fact(infon13, time, [agente:id5, arg:id4], 1, tes(f4_ta), id2)
included(tr(f4_ta), id1)
overlap(tes(f4_ta), td(f4_ta))

tb.obj - [maria lo aspettava]
loc(infon25, id6, [arg:main_tloc, arg:tes(f4_ta)])
ind(infon26, id7)
fact(infon27, inst_of, [ind:id7, class:donna], 1, univ, univ)
fact(infon28, name, [maria, id7], 1, univ, univ)
fact(id8, aspettare, [actor:id7, tema_nonaff:id3], 1, tes(f4_tb), id2)
fact(infon31, isa, [arg:id8, arg:pr], 1, tes(f4_tb), id2)
fact(infon32, isa, [arg:id9, arg:tloc], 1, tes(f4_tb), id2)
fact(infon33, imp, [arg:id9], 1, tes(f4_tb), id2)
fact(infon34, time, [agente:id9, arg:id8], 1, tes(f4_tb), id2)
included(tr(f4_tb), id6)
finished_by(tes(f4_tb), tes(f4_ta))

td.obj - [lei lo insultò]
fact(id10, insultare, [agente:id7, tema_aff:id3], 1, tes(f4_td), id2)
fact(infon44, isa, [arg:id10, arg:ev], 1, tes(f4_td), id2)
fact(infon45, isa, [arg:id11, arg:tloc], 1, tes(f4_td), id2)
fact(infon46, pass_rem, [arg:id11], 1, tes(f4_td), id2)
fact(infon47, time, [agente:id11, arg:id10], 1, tes(f4_td), id2)
included(tr(f4_td), id6)
after(tes(f4_td), tes(f4_ta))

ENTITIES OF THE WORLD
INDIVIDUAL: id3 RELEVANCE SCORE: 18
ind(infon5, id3)
fact(infon6, inst_of, [ind:id3, class:uomo], 1, univ, univ)
fact(infon7, name, [mario, id3], 1, univ, univ)
fact(id4, correre, [agente:id3, locativo:id2], 1, tes(f4_ta), id2)
fact(id8, aspettare, [actor:id7, tema_nonaff:id3], 1, tes(f4_tb), id2)
fact(id10, insultare, [agente:id7, tema_aff:id3], 1, tes(f4_td), id2)

INDIVIDUAL: id7 RELEVANCE SCORE: 12
ind(infon26, id7)
fact(infon27, inst_of, [ind:id7, class:donna], 1, univ, univ)
fact(infon28, name, [maria, id7], 1, univ, univ)
fact(id8, aspettare, [actor:id7, tema_nonaff:id3], 1, tes(f4_tb), id2)
fact(id10, insultare, [agente:id7, tema_aff:id3], 1, tes(f4_td), id2)

DISCOURSE STRUCTURE AND RELATIONS

root:new(1-1)
clause:1-1
topics:[expected:id3:mario]
main_fact:correre([id3:mario, id2:casa], 1, id2)
ref_int:tint(tes(f4_ta), [])
temp_rel:overlap(tes(f4_ta), td(f4_ta))
disc_rel:narration
disc_str:1-[1]
disc_dom:objective
p_o_view:narrator

down:down(1-1)
clause:2-2
topics:[main:id3:mario, secondary:id7:maria]
main_fact:aspettare([id7:maria, id3:mario], 1, id2)
ref_int:tint(tes(f4_ta), [tes(f4_tb)])
temp_rel:finished_by(tes(f4_tb), tes(f4_ta))
disc_rel:elaboration
disc_str:1-[1, 2]
disc_dom:objective
p_o_view:narrator

```
up:to(1-1)
clause:3-3
topics:[main:id7:maria, secondary:id3:mario]
main_fact:insultare([id7:maria, id3:mario], 1, id2)
ref_int:tint(tes(f4_td), [])
temp_rel:after(tes(f4_td), tes(f4_ta))
disc_rel:narration
disc_str:2-[3]
disc_dom:objective
p_o_view:narrator
```

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Acknowledgements

I am grateful to a long list of people who collaborated with me at the organization of the computational lexicon LIFVE at various times in various ways and they are:
Anna Cardinaletti, Giuliana Giusti, Paola Merlo, Roberto Dolci, Laura Brugè, Monica Dan, Giovanni Alberti, Marialuisa Furlan, Analisa Sanson, Andrea Cacco, Emanuele Pianta, Gerhard Bruegger, Francesco Stiffoni.
Thanks also in particular to Dario Bianchi and Emanuele Pianta who worked at the semantic modules of GETA_RUN. Obviously they do not have to agree with the contents of this paper, and all faults are clearly mine.