

Temporal views as abstract relations

Allan Ramsay
Dept of Computation, UMIST,
PO Box 88, Manchester M60 1QD, UK
Allan.Ramsay@umist.ac.uk

2002 IEEE. Personal use of this material is permitted. However, permission to reprint/republish this material for advertising or promotional purposes or for creating new collective works for resale or redistribution to servers or lists, or to reuse any copyrighted component of this work in other works must be obtained from the IEEE.

Abstract

Many natural languages use prepositions to mark relations between entities of various kinds – between physical entities and their spatial locations, between temporal entities and their temporal locations, between abstract entities of various kinds (e.g. between ideas and their ‘mental locations’). In the current paper I will show that the consequences of using prepositions to relate temporal entities emerge naturally from the basic interpretations of the prepositions themselves together with a very weak logic of events, where I take it that prepositions denote abstract relations whose significance only emerges when properties of the related items are taken into consideration.

1. Prepositions as abstract relations

“*in*: preposition expressing *inclusion* or position within limits of space, time, circumstance, etc.”

Pocket Oxford Dictionary of Current English, 1970

Consider the following sets of sentences:

- (1) a. He drove from London to Paris.¹

¹(1a) to (1c) are taken from [1].

- b. He drove from dawn to dusk.
c. He copied it from his hard drive to a floppy.
d. I got the RAE results from the Guardian².

- (2) a. I saw a man in the park.
b. I saw him in January.
c. I’ve got an idea for a paper about time in my mind, but I don’t know how it will work out.
d. I’ve got 230 people in my AI class next term.

- (3) a. I saw him at the station.
b. I saw him at two o’clock.
c. He seemed to be at his wits’ end.

All of these, apart perhaps from the very last one, seem to be entirely natural. The prepositions that appear in them, however, clearly link very different kinds of things. In the (a) examples the ground for the relation denoted by the PP is a physical location, in the (b) examples it is a temporal location, in the (c) and (d) examples it seems to be some sort of abstract entity. Is one of these relations primary, with the others as some kind of metaphorical extension, or is there some common element which gets extended in different ways depending on the nature of the ground?

This is not, in this paper, a question about the history of prepositions, either over the evolution of the language across the centuries or within each language learner. It may be that, at least historically, the spatial interpretations of some of these prepositions come first, but there is very little evidence that the spatial readings predominate in the language as it is used today (see Appendix A for an extract from the first 9000 noun-*in*-noun triples in the BNC. There is very little indication here that spatial or temporal uses of ‘*in*’ are particularly common³). The aim of the current paper is to see whether it is possible to provide a single uniform account of the meaning of prepositions like the ones in (1)–(3) which shows how the contribution they make to the meaning of the sentence, and in particular to the temporal structure of the reported event, arises from a simple core meaning for the preposition in conjunction with the key properties of the entities being related.

²because they ranked UMIST higher than anyone else did!

³The process of extracting these was not sensitive to the possibility that the PP modifies a VP rather than a nominal, but in any case it is the nature of the ground that has most effect on the type of relation, and there will not be much wrong with the choice of ground in these examples.

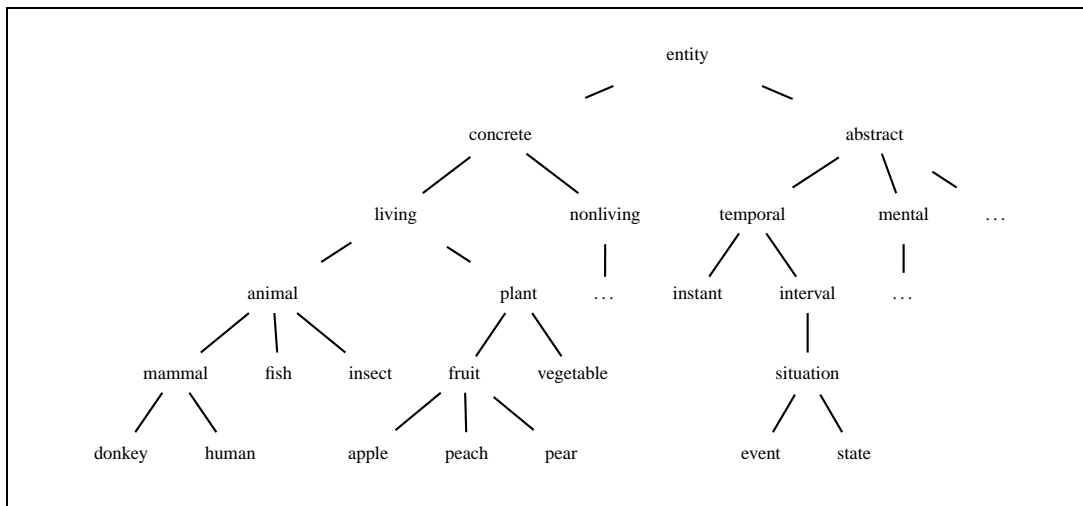


Figure 1. Extracts from the basic sort hierarchy

$$\begin{aligned} \exists A : \{ & A \in interval \& real(A) \& ends_before(ref(\lambda B(now(B))), A) \} \\ \exists C : \{ & aspect(simple, A, C) \\ & \theta(C, agent, ref(\lambda D(centred(D, ref(\lambda E(cdiscourse(E)))) \& m(D)))) \\ & \& drive(C) \& C \in event \\ & \& from(C, ref(\lambda F(named(F, London) \& to(F, ref(\lambda G(named(G, Paris)))))) \} \end{aligned}$$

Figure 2. A driving event that started in London and ended in Paris

2. Multiple views

The key observation is that most objects can be seen from multiple points of view. A reading event, for instance, can be seen as a physical object involving light being reflected from a marked surface into someone’s eyes, as a temporal object with a duration over which the event takes place, and as a mental object involving transfer of information into someone’s mind.

Different events have different sets of views, where each view is assigned a position within a natural kind hierarchy for which we have a constant (very short!) time algorithm for checking whether two types are compatible (i.e. that they lie on the same branch of the hierarchy). We write $X \sim Y$ to say that X and Y have compatible types (so that if some object was described as being *human* at one point in our knowledge base and at another as being *animal* then the algorithm would check that these assignments are compatible with reference to the type hierarchy, extracts from which are shown in Fig. 1).

Reading has physical, temporal and mental views, eating has physical and temporal views,

knowing has mental and temporal views, and so on. This is unsurprising. Different events are different, involving different kinds of things. If the object of an event is a mental entity such as a thought then the event will necessarily have a mental view, if its object is a physical entity such as a peach then the event will have a physical view. It is, however, notable that *all* events have a temporal view. We therefore take it that the primary view of an event is as a temporal object. The idea that you can see a single object from a number of different points of view is similar to Pustejovsky’s [6] QUALIA STRUCTURE, except that the current analysis allows an arbitrary number of views, of arbitrary types, whereas Pustejovsky argues for a small fixed range of qualia. We denote the fact that X is of type E by writing $X \in E$.

We exploit this in the analysis of natural language utterances by constructing a logical form which aims to contain all and only the information that is explicitly encoded by the sentence, and then backing this up with a set of meaning postulates which flesh out the content of the terms that appear in the logical form. For (1a), for in-

stance, we obtain the logical form in Fig. 2.

A logical form of this kind, however, does nothing for you unless you know what driving is like, what agents do, and so on. We therefore back up our logical forms with sets of meaning postulates, as in Fig. 3.

These MPs start to describe what driving is like. The first MP in Fig. 3 says things about the temporal view of a driving event. The second one says that you can view a driving event as a concrete (i.e. physical) path. The third says that the person in charge of a driving event is one of the things that is affected by it.

We thus have two views of our driving event, one coming directly from the logical form saying that it can be seen as a temporal entity and one arising from the MP saying that it can be seen as physical path. What can we do with them?

Clearly we have to know what extended closed bounded intervals are like, since the MPs in Fig. 3 say that driving events can be seen as closed bounded intervals, and what paths are like, and we also have to know what ‘to’ means, since the logical form says that this driving event is ‘to’ Paris. Fig. 4 shows the basic axioms we use for reasoning about time and about paths in general, and Fig. 5 explains what ‘to’ means.

The set of axioms Fig. 4 in is very weak. It says that the set of instants is partially ordered; that some intervals are bounded above and/or below; that some bounded intervals have greatest lower bounds and/or least upper bounds, which we call their starts and ends; and that some intervals contain their starts and ends⁴. Note that we do *not* insist that every bounded interval has a start and an end: the temporal logic that underlies natural language does not require intervals to have this property, and indeed in some cases it seems useful to consider bounded intervals that lack greatest lower bounds or least upper bounds. We are therefore assuming that the idea of time that underpins natural language has a model which is either smaller than the set of real numbers (e.g. that it maps onto the rationals) or larger than the set of reals (e.g. that it includes infinitesimals [3]). The axioms in Fig. 4 also say nothing about whether the time line is dense, though most reasonable models will have this property.

The key MP for ‘to’ is given in Fig. 5 (the one for ‘from’ is too similar to include).

This MP says that if $to(A, B)$ holds then if C and D are views of A and B and the end E of

⁴Fig. 4 concentrates on lower bounds: the axioms dealing with upper bounds are exactly analogous.

C is of the same general type as D then D and E are the same thing. This MP looks vacuous, in the same way as the definition of ‘in’ quoted at the start of the paper, since it seems merely to reduce $to(X, Y)$ to $end(X, Y)$ without saying what ends are like. In fact it does most of the important work of explaining what ‘to’ means. Its job is to pick out the relevant facets of the figure and the ground – to pick out that it is the concrete view of the driving events that goes to Paris, but the temporal view that goes to dusk, saying that if the ground is the kind of thing that *could* be the end of the figure then it *is* the end of the figure. The role of the preposition, then, is to *select* appropriate views. Anything further that emerges will follow from the nature of the selected items: Fig. 6 shows the temporal model that emerges from assigning dawn and dusk to be the start and end points of the temporal view of John’s drive (this temporal model contains those instants and intervals that are linked to the temporal view of the event itself. Interesting facts that the system has about those instants and intervals are listed below the bar chart⁵).

We can axiomatise ‘in’ similarly. To paraphrase the definition of ‘in’ from the start of the paper, X is in Y if each part of X is a part of the ‘envelope’ of Y , where the envelope of Y is a set of ‘limits of space, time, circumstance’.

As with Fig. 5, the lexical item ‘in’ invokes the more abstract notion of the *envelope* of some view of the ground. Again there is no restriction on what kind of thing this view is. We just have to find compatible views of the figure and the ground, and then the membership relation will do the rest.

Just what the membership relation will do depends on the kinds of sets we are talking about. If every member of one interval I_1 is a member of another, bounded, interval I_2 then, in particular, every member of I_1 is after or equal to the start of I_2 and before or equal to its end. This follows from the axioms in Fig. 4.

For other kinds of sets other conclusions will follow. This is entirely natural – being in a park is quite different from being in January or being in a class, even if in each case ‘in’ just means set membership. The consequences of being a member of an ordered set such as a temporal in-

⁵the model shown in Fig. 6, like all the other models shown in this paper, was obtained automatically from the given axioms and logical forms.

⁶We are using Reichenbach’s [13] tri-partite distinction between event time, speech time, called *now* for short, and ‘reference time’, which is related to speech time by the tense of the utterance and to event time by its aspect.

$$\begin{aligned} \forall A : \{drive(A)\} & extended(A) \\ & \&bounded(A) \&closed(A) \\ \forall A : \{drive(A)\} \\ & \exists B view(A, B) \& path(B) \\ & \&(B \in concrete) \\ \forall A : \{drive(A)\} \\ & \forall B : \{\theta(C, agent, B)\} \\ & \theta(C, object, B) \end{aligned}$$

Figure 3. What is driving like?

$$\begin{aligned} \forall A : \{A \in instant\} \\ & \forall B : \{B \in instant\} \\ & \quad \forall C : \{C \in instant\} A > B \& B > C \rightarrow A > C \\ \forall A \forall B \neg(A > B \& B > A) \\ \forall A : \{lbounded(A)\} \exists B \forall C : \{member(C, A)\} C > B \\ \forall A lbounded(A) \leftrightarrow lbounded(A) \& ubounded(A) \\ \forall A : \{lclosed(A)\} \exists ! B member(B, A) \& start(B, A) \\ \forall A : closed(A) \leftrightarrow lclosed(A) \& uclosed(A) \\ \forall A \forall B : \{member(B, A)\} \forall C : \{start(C, A)\} B \geq C \\ \forall A : \{extended(A) \& A \in interval\} \\ & \forall B : \{start(B, A)\} \forall C : \{end(C, A)\} C > B \\ \forall A : \{path(A)\} closed(A) \end{aligned}$$

Figure 4. A weak logic of time (and paths)

$$\begin{aligned} \forall A \forall B : \{to(A, B)\} \\ & \forall C : \{view(A, C)\} \\ & \quad \forall D : \{view(B, D)\} \\ & \quad \quad \forall E : \{end(E, C) \& D \sim E\} \\ & \quad \quad \quad D = E \end{aligned}$$

Figure 5. What ‘to’ means

terval are stronger than the consequences of being a member of an unordered set: that’s what it means to say that a set is ordered. But the consequences of saying that one bounded interval is a subset of another are simply the consequences that arise from saying that intervals are ordered sets of instants. The temporal relations that arise from this for (2b) are shown in Fig. 8.

The general idea, then, is that prepositions pick out compatible views of the figure and ground and relate elements of those views.

Things get a bit more complicated when we consider the examples in (3):

- (3) a. I saw him at the station.
b. I saw him at two o’clock.

- c. He departed at two o’clock.
d. He arrived at two o’clock.

The first pair of examples here seem very like the ones in (2). We have temporal and physical views of the same event, with (3a) locating the physical view at a physical location and (3b) locating the temporal view at a temporal location.

What part of the event is located at two o’clock? In (3c) it seems to be the start of the event, whereas in (3d) it seems to be the end. It seems as though ‘at’ not only selects the appropriate view, it also selects different elements of that view depending on the nature of the event.

Arriving and departing have fairly intricate temporal structures. Arriving events don’t seem

to have starts, though they do have clearcut ends. When you say that John arrived at the party at 7:00, you leave the time and place that he departed from unspecified. Clearly he must have come from somewhere, and he must have left that place at some time, but the sentence ‘*John arrived at the party at 7:00*’ says nothing about where he has come from or when he left. We capture this by saying that arriving events have lower bounds and least upper bounds⁷: once you have arrived, you can’t go on arriving, so there is a point at which an arriving event ends. Similarly saying ‘*John left the party at 11:30*’ carries no information about where he went or when he got there, so that departures have upper bounds and greatest lower bounds.

Why do arriving and departing differ in this way? Arriving is COMPLETE when the entity is at its destination. The moment John got to the party he had arrived – before he got there he hadn’t arrived, once he was there he had. So the (temporal) end of an arriving event coincides with its completion, at which point the physical location of the arriver is fixed. Departing is complete as soon as the departing item has moved away from its source – at something like ‘the next instant after its start’ – but nothing specific is known about its location at this point.

We use the MPs in Fig. 9 to capture some of these properties of arriving and departing.

The key differences are that an arrival’s (temporal) end and completion are the same point, whereas a departure’s completion is immediately after its start⁸; and that the physical view of an arrival also has a completion, namely the place where you are when you have arrived, whereas the physical view of a departure does not.

Given these descriptions of arriving and departing, we can characterise ‘*at*’ as in Fig. 10.

This just says that if D is the kind of thing that could be the completion of C then it is, just as with the mapping from ‘*to*’ to *end* and from ‘*in*’ to *envelope*.

The temporal structure of the models that arise from (3c) and (3d) is show in Fig. 11. The key differences are that the departure is complete at some time shortly after 2:00⁹, whereas the arrival is complete exactly at 2:00, and that the reference

⁷Remember that we are not assuming that the time line is isomorphic to \mathcal{R} , so that sets with lower bounds need not have *greatest* lower bonds.

⁸The notion of the ‘next instant’ is widely used in everyday reasoning, and can be given a firm mathematical underpinning via non-standard analysis.

⁹very shortly after 2:00, but it’s not possible to show infinitesimal intervals in L^AT_EX!

interval associated with the arrival lies between the end of the event and speech time, whereas the reference interval for the departure overlaps the event itself. In other words, the arrival is definitely over, whereas although the departure is complete, in the sense that John has left, it may not be over, since he may still be going away.

3. Linking views

The discussion in section 2 showed that fine distinctions in reported temporal structure can be made on the basis of a rather weak logic of intervals and instants and a careful analysis of what particular events are like. We also need, however, to link the various views of the event so that we can infer what is true at various times. We need to know not just that a departure is complete immediately after it has begun, but also that when it is complete the distance from the physical start is greater than 0, and likewise for any other kind of event that we want to reason about.

To do this, we need to be able to reason about ‘truth in a context’. E in the first MP in Fig. 12 is an instant, namely some arbitrary member of A , and likewise for E and F in the second MP. What Fig. 12 says is that as a departure proceeds the agent gets further away from the start point¹⁰. In order to cope with such statements we have to be able to carry out inference at different instants, or in general in different contexts (e.g. in the context of what someone knows or believes, or of what one person believes about someone else’s beliefs).

The inference engine we use is an extension of Manthey & Bry’s [4] MODEL GENERATION theorem prover, adapted to be more efficient [7] and to cope with untyped fine-grained intensionality [8, 11]. The changes to Manthey & Bry’s original presentation involve, among other things, including a commentary on the progress of a proof, in the form of a LABEL [2].

In order to do proofs in different contexts, we include a description of the context in which a proof is being carried, and of the contexts in which a rule is applicable, in the label. This description of the context comes as a list, since we need to be able to nest contexts in order to be able to reason about nested beliefs. As the proof proceeds, the availability of a given fact or rule in the desired context is verified. This closely resembles Wallen’s [17] use of PREFIXES for reasoning about modal logics, where the prefix of a formula is a sequence that describes the ‘route’ to

¹⁰So if you are no longer moving away then you are no longer departing.

$$\begin{aligned}
&\forall A : \{arrive(A)\}lbounded(A)\&uclosed(A) \\
&\forall A : \{arrive(A)\}\forall B : \{end(B, A)\}completion(B, A) \\
&\forall A : \{arrive(A)\} \\
&\quad \exists B : \{view(A, B)\&(B \in concrete)\} \\
&\quad \quad \exists C : \{C \in concrete\}completion(C, B) \\
&\forall A : \{depart(A)\}ubounded(A)\&lclosed(A) \\
&\forall A : \{depart(A)\} \\
&\quad \forall B : \{start(B, A)\}\exists C(C \in instant)\&next(B, C)\&completion(C, A) \\
&\forall A : \{depart(A)\}\exists B : \{view(A, B)\&(B \in concrete)\}\exists C start(C, B)
\end{aligned}$$

Figure 9. What arriving and departing are like

$$\begin{aligned}
&\forall A\forall B : \{at(A, B)\} \\
&\quad \forall C : \{view(A, C)\} \\
&\quad \quad \forall D : \{view(B, D)\} \\
&\quad \quad \quad \forall E : \{completion(E, C)\} \\
&\quad \quad \quad \quad \&D \sim E \\
&\quad \quad \quad \quad D = E
\end{aligned}$$

Figure 10. The meaning of 'at'

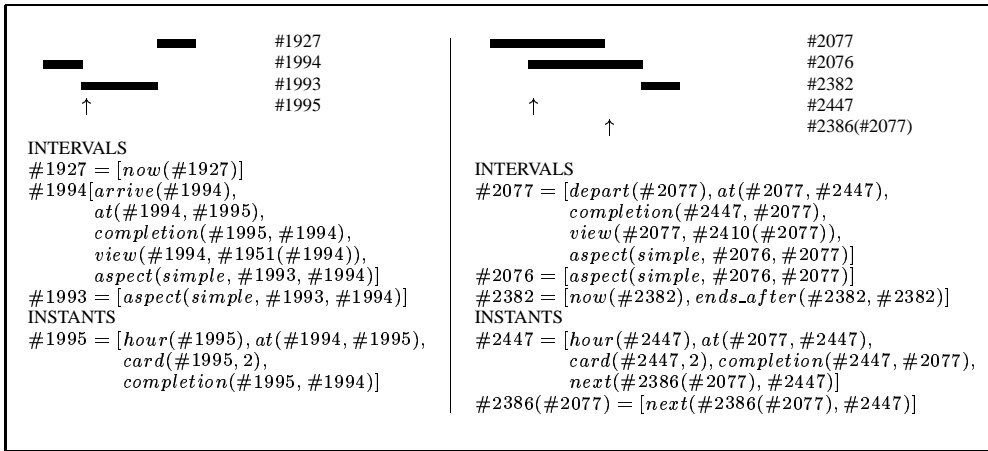


Figure 11. John arrived/deperted at 2:00

the context(s) in which the formula is available, with properties of the accessibility relationship allowing, for instance, propositions which someone knows to be available as facts (since what anyone knows is true).

The full discourse model that emerges from (3d) is shown in Fig. 13. This model contains a great deal of information, including numerous relations between instants and intervals which were omitted from the earlier temporal diagrams (mostly between starts and ends of intervals where nothing is known about the instant apart from the fact that it is the start or end).

Somewhere down the right-hand column is the fact that at time #703, namely two o'clock, the distance #709 between John #677 and the place he has left 707 is greater than it was when he started to leave.

4. Conclusions

The work reported here aims to show that we can obtain the consequences of temporal uses of prepositions on the basis of very abstract descriptions of what a range of prepositions mean, together with a very weak logic of instants and intervals (basically that instants are partially or-

```

 $\forall A : \{depart(A)\}$ 
 $\forall B : \{\theta(A, agent, B)\}$ 
 $\forall C : \{view(A, C) \& C \in concrete\}$ 
 $\forall D : \{start(D, C)\}$ 
 $\forall E : \{member(E, A)\} \exists F dist(B, D, F) @ [E]$ 

 $\forall A : \{depart(A)\}$ 
 $\forall B : \{\theta(A, agent, B)\}$ 
 $\forall C : \{view(A, C) \& C \in concrete\}$ 
 $\forall D : \{start(D, C)\}$ 
 $\forall E : \{member(E, A)\}$ 
 $\forall F : \{member(F, A) \& F > E\}$ 
 $\forall G : \{dist(B, D, G) @ [E]\}$ 
 $\forall H : \{dist(B, D, H) @ [F]\} H > G$ 

```

Figure 12. As you depart from somewhere you get further away from it

```

type(#677, animal)      bounded(#705)          member(#712, #704)
caused(#677, #705)     type(#705, event)    #712 > #715
intended(#677, #705)  ends_before(#705, #704) #712 ≥ #712
#696 ≥ #712            $\theta$ (#705, agent, #677) start(#712, #704)
#696 ≥ #711          view(#705, #710)    ends_after(#713, #713)
type(#703, instant)  at(#705, #703)      #716 > #703
card(#703, 2)        depart(#705)        #716 > #706
hour(#703)           type(#706, instant) #717 > #712
member(#703, #705)   member(#706, #705)  #717 > #711
#703 > #706          #706 > #714        aspect(simple, #704, #705)
#703 > #714          #706 ≥ #706        infelicitous(now(#697))
completion(#703, #705) start(#706, #705)   hour(#703)
closed(#704)         next(#706, #703)    card(#703, 2)
lclosed(#704)       start(#707, #710)  depart(#705)
uclosed(#704)       type(#710, concrete) at(#705, #703)
lbounded(#704)      type(#711, instant) dist(#677, #707, #708) @ [#706]
ubounded(#704)     member(#711, #704) dist(#677, #707, #709) @ [#703]
bounded(#704)       #711 > #715        #709 > #708
type(#704, interval) #711 ≥ #703        ends_before(#704, #697)
ends_before(#704, #697) #711 ≥ #706        type(#704, interval)
lclosed(#705)       #711 ≥ #711      type(#705, event)
lbounded(#705)     end(#711, #704)    aspect(simple, #704, #705)
ubounded(#705)     type(#712, instant)  $\theta$ (#705, agent, #677)

```

Figure 13. Everything we know as a result of (3d)

dered, and that intervals are sets of instants which may be bounded and may or may not have least-upper and greatest-lower bounds).

This work gives a concrete implementation of ideas discussed by Dowty [1], who in turn refers to ‘...van Fraassen’s notion of *logical space*. There will be as many axes of logical space as there are kinds of measurement. [...] *Each axis might have a different mathematical structure according to the discriminations that can be appropriately made in each case*’ (p. 126, my italics).

All the logical forms and temporal models given above were produced using the Parasite language understanding system [10, 12, 14]. The treatment of aspect described in the current paper is a simplification of the treatment given in

[9], which showed how to cover the basic facts about tense and aspect as discussed by [15] and [16] whilst dealing with the apparent cases of ‘coercion’ described by [5] as emergent properties of the interaction between aspect and aktionsart, since including the full treatment of aspect would merely have obscured the main point. The aim of the current paper was to bring out the abstract nature of prepositional relations, and to show how the detailed consequences of temporal uses of such terms emerge from combining the view of intervals as sets of instants, the general properties of ordered sets, and the very abstract characterisations of the prepositions themselves.

The model in Fig. 13 shows the amount of information that is exploited in model construc-

tion. The theorem prover does not provide special purpose facilities for dealing with time – not for dealing with the ordering relations illustrated through the body of the paper, nor for reasoning about which propositions are true at which point. The facts about order are simply treated as first-order rules, so that the transitivity of temporal order, for instance, is simply expressed as $\forall T_1 \forall T_2 \forall T_3 (T_1 < T_2 \& T_2 < T_3 \rightarrow T_1 < T_3)$. Reasoning about what is true at a given instant is taken to be an instance of contextual reasoning, and is dealt with by the general mechanism of including a description of the context in the label. Reasoning about time may be complex, but it is not different in kind from other sorts of reasoning.

References

[1] D. R. Dowty. *Word Meaning and Montague Grammar*. D. Reidel, Dordrecht, 1979.

[2] D. M. Gabbay. *Labelled Deductive Systems*. Oxford University Press, Oxford, 1996.

[3] H. J. Keisler. *Foundations of Infinitesimal Calculus*. Prindle, Weber and Schmidt, Boston, Mass., 1976.

[4] R. Manthey and F. Bry. Satchmo: a theorem prover in Prolog. In *Proceedings of the 9th International Conference on Automated Deduction (CADE-9)*, volume 310 of *Lecture Notes in Artificial Intelligence*, pages 415–434, Berlin, 1988. Springer-Verlag.

[5] M. Moëns and M. Steedman. Temporal ontology and temporal reference. *Computational Linguistics*, 14(2):15–28, 1988.

[6] J. Pustejovsky. The generative lexicon. *Computational Linguistics*, 17(4):409–441, 1991.

[7] A. M. Ramsay. Generating relevant models. *Journal of Automated Reasoning*, 7:359–368, 1991.

[8] A. M. Ramsay. A theorem prover for an intensional logic. *Journal of Automated Reasoning*, 14:237–255, 1995.

[9] A. M. Ramsay. Aspect and aktionsart: fighting or cooperating? In J.-I. Tsujii, editor, *Proceedings of the 16th International Conference on Computational Linguistics (COLING-96)*, pages 889–894, Copenhagen, 1996.

[10] A. M. Ramsay. Direct parsing with discontinuous phrases. *Natural Language Engineering*, 5(3):271–300, 1999.

[11] A. M. Ramsay. Theorem proving for untyped constructive λ -calculus: implementation and application. *Logic Journal of the Interest Group in Pure and Applied Logics*, 9(1):89–106, 2001.

[12] A. M. Ramsay and H. Seville. Models and discourse models. *Journal of Language and Computation*, 1(2):167–181, 2000.

[13] H. Reichenbach. *The Direction of Time*. University of California Press, Berkeley, 1956.

[14] H. Seville and A. M. Ramsay. Making sense of reference to the unfamiliar. In M. Kay, editor, *Proceedings of the 18th International Conference on Computational Linguistics (COLING-2000)*, pages 775–781, Universität des Saarlandes, July 2000.

[15] C. S. Smith. *The Parameter of Aspect*. Kluwer Academic Publishers, Dordrecht, 1991.

[16] A. G. B. ter Meulen. *Representing Time in Natural Language: the dynamic interpretation of tense and aspect*. Bradford Books, Cambridge, Mass., 1995.

[17] L. Wallen. Matrix proofs for modal logics. In *IJCAI-87*, 1987.

Appendix A: noun-*in*-noun triples from the BNC

abnormalities in limb	achievements in cricket
abnormalities in monkeys	acid in activity
abnormality in structure	acid in raindrops
abortion in principle	acid in rivers
absolutist in tone	acid in tea
absorption in life	acidity in rainfall
abuse in childhood	acids in proteins
abuse in schools	acres in coppices
abuse in sibilings	acres in extent
abuses in debt	acres in size
acceleration in bedrock	acres in south
accident in history	act in theatres
accidents in life	action in cases
accidents in summer	action in cells
accommodation in advance	action in confidence
accommodation in areas	action in defence
accommodation in rooms	action in detention
accomplices in crime	action in privacy
account in protest	action in sight
account in transport	action in time
account in volume	actions in court
accountability in broadcast	actions in fiction
accountants in turn	actions in office
accounts in newspapers	activities in day
accounts in order	activities in drama
accuracy in illustration	activities in parts
achievement in arts	activities in words
achievement in education	activity in body
achievement in games	activity in flavonoids
achievement in house	activity in man
achievement in life	activity in painting
achievement in verse	activity in rats
achievements in animals	activity in school
achievements in chess	activity in summer