Integration of Spatial and Temporal Information Produced by a Natural Language discourse

Laurent Romary

Integration of spatial and temporal information produced by a natural language discourse.

Laurent ROMARY
CRIN-INRIA Lorraine, B.P. 239, 54506 Vandœuvre Lès Nancy
ma.: romary@loria.fr
phone : 83 91 23 88
fax : 83 41 30 79

Summary: In the general context of a man-machine dialogue system, the adequate representation of the different kinds of data given by the user is very important. We present in this paper a method for representing temporal and spatial pieces of knowledge in an integrated manner, based on previous works done on *temporal zones*. Firstly, we present the two levels of time and space seperately, though they work on the same principles. Then, we show how these notions interact with each other through the definition of an *object-universe*, a structure which bears the different states and events undergone by any object referred to in a NL discourse. Within this representation, we propose a mechanism to acquire knew pieces of information by comparing two complex space-time structures. This leads us to show that the two levels are complementary to compute a specific situation in the world. Finally, we briefly address the use that can be made of this model to the understanding of a series of utterance in the present tense (description of a situation) and to the representation of the notion of event.

Keywords: knowledge representation, time, space, reference.

Résumé : Dans le cadre de la mise en œuvre d'un système de dialogue homme-machine, il est primordial de pouvoir représenter les différentes informations fournies par l'utilisateur. C'est ainsi que nous présentons dans cet article une méthode de représentation des informations spatiales et temporelles sous une forme intégrée, qui s'appuie sur des travaux antérieurs relatifs aux *zones temporelles*. Dans un premier temps, décrivons les deux niveaux du temps et de l'espace séparément, bien qu'ils s'appuient sur les même principes. Puis, nous montrons comment ces notions interagissent ensemble en définissant un *univers d'objet* qui permet de suivre les différents états et événements liés à un objet décrit dans un discours en langage naturel. Dans ce cadre, nous proposons un mécanisme pour acquérir de nouvelles informations en comparant deux structures complexes sur le plan spatial et le plan temporel. Cela nous conduit à montrer que les deux niveaux sont complémentaires pour calculer automatiquement une situation particulière dans le monde décrit. Nous abordons briévement l'application de ce modèle au problème de l'intégration d'une suite d'énoncés au présent (description d'une situation) et à la représentation de la notion d'événement.

Mots-clef : représentation des connaissances, temps, espace, référence.

1. General context.

The work presented in this paper aims at describing a general framework for the representation of spatial and temporal information produced by natural language. Whereas the main purpose of our project at the CRIN (Nancy) is to define a man-machine dialogue system in natural language (Carbonell 89), we will essentially focus our attention on knowledge representation rather than on linguistic aspects. The main aspect that has guided our study is that language conveys elements of information that are not necessarily complete if we consider the world to be described. As a matter of fact, there should exist a mechanism to acquire new pieces of information and relate them to those previously memorized. This mechanism is what we can actually call understanding a discourse as compared to understanding utterances.

There are few works combining both spatial and temporal reasoning in a natural language context. Neumann's NAOS system (1989) has essentially a purpose of NL description from a series of elementary properties given by a vision system. However, this work presents a way of defining events using lower level predicates to abstract high-level spatio-temporal structures. More formal and linguistic aspects are dealt with at the IRIT laboratory in Toulouse where several suggestions have been made to give a semantic of movement with a temporal (Borillo 1990) or a spatial (Borillo 1989) basis.

In our paper, we will not cover a wide range of information to be represented. We will essentially try to illustrate our own view of the articulation between a temporal reasoning scheme and the concrete relations between objects of the world. Then, we will examine a mechanism close to hypothetical reasoning that allows such a framework to acquire new elements of knowledge. This will be applied to two topics related with natural language aspects, namely, the present tense in English and the representation of events.

2. Yet another model.

2.1 General framework

We present in this section the fondamental concepts that form the basis of our temporal and spatial representation. We have chosen to introduce a rather reduced set of objects (e.g. there is no variable), since our purpose is not to give a complete theory of time and space, but rather to show how these two notions combine with each other. As our representation is intended to be a computational one, we do not place ourselves in a model theoretic framework. We prefer to base all our deductions on syntactic rules, for which no precise semantics will be given in a specific domain. Still, it may be possible (e.g. for the temporal aspect of this work) to build up a topological interpretation of the relations that will be presented. Let us first introduce the notion of *fact* in a representational universe.

Let $\mathcal{A}$ be a set of objects and $\mathcal{R}_{\mathcal{A}}$, a set of relation symbols over $\mathcal{A}$, a fact is simply a term composed of a symbol of $\mathcal{R}_{\mathcal{A}}$ together with objects of $\mathcal{A}$ (depending on the arity of the relation). From now onwards, our knowledge on the world will be represented by means of a set of facts, which are those considered as valid in a certain context (temporal or other). New facts are created by applying a series of transition rules in the following form: $\dfrac{f_1, f_2, \ldots, f_n}{f_{n+1}}$

Another kind of rules are incompatibility rules which express that two or more facts cannot be valid at the same time (in the inferential process). Such rules have the following form: $\frac{f_1, f_2, \ldots, f_n}{\Diamond}$.

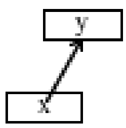
If from a given set of facts E, using any sequence of rules of the preceding type we can infer the diamond $\Diamond$, this will mean that E contains facts which are not compatible with each other, and thus that the operation leading to E should not be preserved.

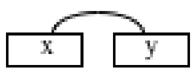
There are two main reasons why we stay at a syntactic level of deduction rather than propose a semantic for it. Firstly, it occurred in many temporal approaches that choosing an interpretation of time within a domain such as the real line for instance led to specific problems when dealing with the status of boundaries and open/closed intervals (Shoham 1988; Allen 85). In the case of Allen's relations (Allen 84), the choice of differentiating the two relations 'before' and 'meets' is based on considerations about the density of the domain in which his intervals should be interpreted. Therefore, we do not want to reduce (or alter) the scope of our analysis by creating specific problems that would not shed any further light on the very problems of knowledge representation. Finally, even if a semantic for our relations could be given, this would entirely be an *ad hoc* transcription of the rules described above and thus this would bring nothing to the ideas born by this work.

2.2 Time representation.

We have already introduced (Romary 1989 a & b) the notion of temporal zone and showed how powerful it is to represent different kinds of information occurring at different levels in a man-machine dialogue in natural language. For the time being, we present the temporal zones under the general frame that we have just defined above. Let $\mathcal{Z}$ be a set of objects called 'Temporal Zones', which will be the only temporal objects to be manipulated. There will be especially no distinction between concepts of process, state or events, which are supposed to appear in a higher level of representation (as a combination of TZs). Let $\mathcal{R}_\mathcal{Z}$ = {in, prec} be the set of relations over $\mathcal{Z}$. Intuitively, 'a in b' represents the inclusion of the time period of the first zone into the time period of the second one, whereas 'a prec b' means that zone a precedes zone b. We have shown [Romary 89a] that defining two temporal relations such as those presented here was sufficient enough when dealing with information given by natural language utterances (as compared with Allen's 7 relations). For example, two relations can represent very acutely the semantics of tenses in English or Japanese (Ogihara 1989, Kamp & Rohrer 1983).

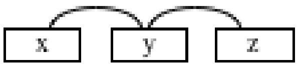
To make inferences on facts built from $\mathcal{Z}$ and $\mathcal{R}_\mathcal{Z}$, we need four transition rules, two expressing the transitivity of our relations (to ease the reading of relations between TZs, we will present them in a graphical representation with the following conventions :

x in y -> 

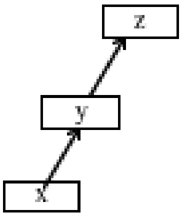
, x prec y -> 

).

$$\frac{\text{prec}(x,y),\ \text{prec}(y,z)}{\text{prec}(x,z)}$$

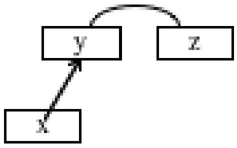


$$\frac{\text{in}(x,y),\ \text{in}(y,z)}{\text{in}(x,z)}$$

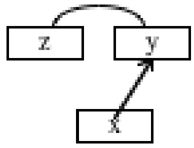


and two relations expressing the result of combining 'in' and 'prec' :

$$\frac{\text{in}(x,y),\ \text{prec}(y,z)}{\text{prec}(x,z)}$$



$$\frac{\text{in}(x,y),\ \text{prec}(z,y)}{\text{prec}(z,x)}$$



Along with those rules, incompatibility rules should be introduced, to express the fact that no pair of objects should be related to each other using more than one different relation :

$$\frac{in\,(x,y), in\,(y,x)}{\lozenge} \qquad \frac{prec\ (x,y), prec\ (y,x)}{\lozenge}$$

$$\frac{in\,(x,y), prec\ (x,y)}{\lozenge} \qquad \frac{in\,(x,y), prec\ (y,x)}{\lozenge}$$

2.3 Space representation.

As we have decided to use one single formalism to represent both time and space, we introduce here the set of objects and relations corresponding to the physical concepts we want to deal with. Let $\mathcal{S}$ be this set of spatial entities (for example those refered to by "Peter", "Paris", "a train") and $\mathcal{R}_{\mathcal{S}} = \{\text{in, by}\}$. There is no ambiguity with the relation 'in' introduced between temporal zones, because these two relations will never appear at the same level of description of objects (cf below). But we took the same name for all the common properties they share. As a matter of fact, the general rules on $\mathcal{S}$ are similar to those defined on $\mathcal{Z}$, except that they should express that 'by' is a commutative relation (we have considered that the space was not oriented). Intuitively, 'S_1 in S_2' indicates that the spatial position of S_1 is fully contained in the spatial position of S_2 and 'S_1 by S_2' means that the spatial positions of S_1 and S_2 are completely seperated.

Hence, we define the following rules :

Transition rules :

$$\frac{\text{in}(x,y),\ \text{in}(y,z)}{\text{in}(x,z)} \qquad \frac{\text{in}(x,y),\ \text{by}(y,z)}{\text{by}(x,z)}$$

Incompatibility rules :

$$\frac{in\,(x,y), by\,(x,y)}{\lozenge} \qquad \frac{in\,(x,y), in\,(y,x)}{\lozenge}$$

And finally, we need to introduce the following **commutativity rule**:

$$\frac{\text{by}(x,y)}{\text{by}(y,x)}$$

2.3 Combination of spatial and temporal information.

If we do not consider abstract concepts (freedom, democracy), there are in fact two main categories of objects referred to (in a broad meaning) in natural language, which a knowledge representation system should be able to take into account:

- pure temporal objects, which express events or states in the world (for example *"the arrival of the train", "the train arrives", "to be blue"* etc…).
- more concrete objects, which we will call abusively "physical" objects (*"the train"*, *"Paris"*, *"Peter"…*)

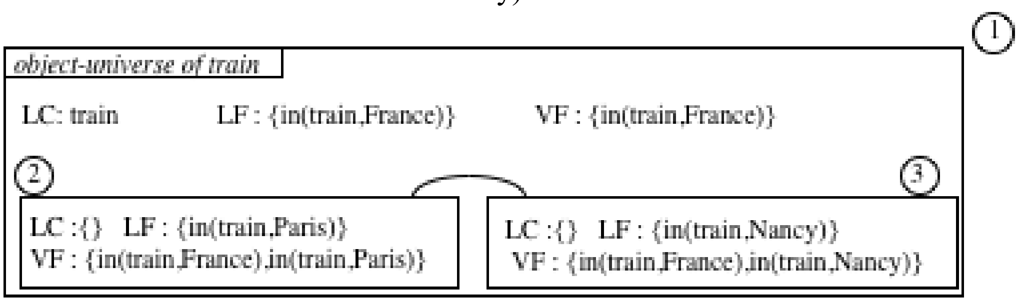
Each object in this latter category may be born by an object of the first one. Since temporal object are represented in our model as temporal zones, it would seem natural to define a physical object inside the temporal zone where it occurs as a part. However, we would like to record the different changes undergone by an object and not have it be dependent from a specific event or state. Suppose for example that we want to consider a train, for which we want to represent the following uttered characteristics:

- *"the train is in Paris"*
- *"the train is in Nancy"*

If the expression "the train" refers to the same object in both utterances, those two states should be linked together, possibly by a temporal relation such as those defined in section 2.2. But there should be a way to state that there is a single variable in the two facts : 'in(train,Paris)' and 'in(train,Nancy)'. Thus, we define a special entity called an *object-universe*, which is a TZ which has the following structure:

object-universe =
Local Constants (LC)
Local Facts (LF)
Valid Facts (VF)

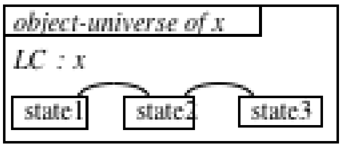
For example the object above defined is represented as follows (we will not represent all the fields when it is not necessary):



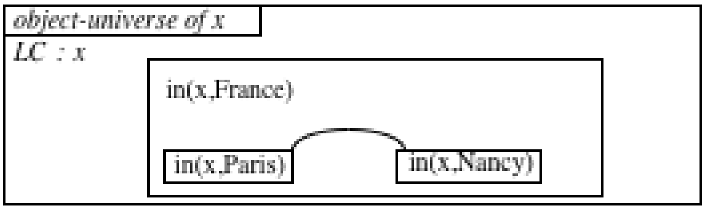
In this figure there are three TZs: zone 1 is the object-universe of 'train', i.e. the whole period along which we have some information about 'train' and zones 2 and 3 are included in zone 1 (the drawing of the inclusion relation has been removed for the sake of clarity). Here, we have supposed that zone 2 preceded zone 3. For every TZ included in a zone where a local constant is defined, this constant is known by the zone and can be used to form any fact as necessary.

We thus consider a physical object as something which representation is continuous (on a temporal point of view) within our model. This continuity is conveyed through a specific temporal zone.

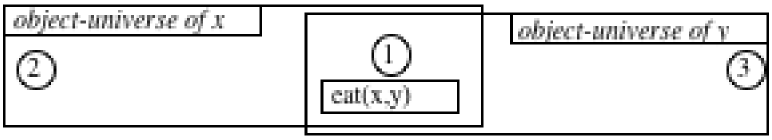
This way of representing the different changes of an object could make us think of McDermott's chronicles (1982), in which the different states of a system are linked one after another. As a matter of fact there could be an object represented by a sequence of states such as follows for 'x':



But we have seen that our temporal model could as well represent embedded structures where the existence of the local constants are propagated. For example, we know that, being in France, x has successively been in Paris and in Nancy, as follows:



Another important difference with McDermott's chronicles is that the record of facts in a structured bundle of TZs is done at the level of each object to be represented, and not globally for the whole world. Let us take for example the case in which two object-universes for x and y are involved in a binary relation such as 'eat(x,y)'. The TZ corresponding to this event is shared by the two object-universes and thus can be conveyed in inferential operations in both of them. This situation is represented below :



If such "bridges" between object-universes did not exist, there would be no reason to make any inference between zones 2 and 3 (see above).

Such a representation is not useful unless there exist some rules and restrictions concerning the interaction between the spatial facts and the temporal zones that bear them. For example in the embedded structure quoted above, it is necessary that the fact 'in(x,Paris)' be compatible with 'in(x,France)'. Otherwise the whole structure would be contradictory. Hence, we introduce a mechanism to propagate facts along the inclusion relation between TZs :

Propagation rule:

Let Z_0 and Z_1 be two temporal zones (together with their Local Variables, Local Facts and Valid Facts) then the following rule can be applied to Z_0 and Z_1.

If (Z_0 in Z_1) then $Z_0.VF \supset Z_1.VF$

and Z.VF can be computed as follows :

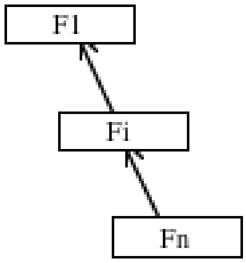
$Z.VF = closure(Z.LF \cup [\bigcup_{(\text{ Y such that Z in Y})} Y.VF])$, where *closure()* is a function applying any possible rule to the considered set.

We can remark here that our propagation rule is close to the definition of state given by Allen: for p a property and i an interval we have (using Allen's notation) :

$$hold(p,i) \Leftrightarrow (\forall\ j\ (j \text{ in } i) \Rightarrow hold(p,j))$$

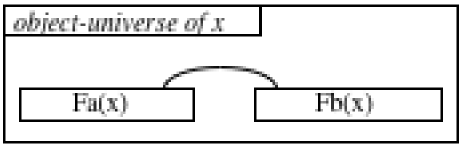
Effectively, we conduct here a kind of analysis based on states, but, unlike Allen, we do not apply our rule to any sub-parts of a given interval. As we work on temporal zones, we can restrict the application of our rule to the reduced number of zones that have been declared as being contained in a given one.

More generally, if we have a n-level structure of temporal zones with, at each level, F1, …Fn as local facts, at level i (cf scheme below) we must make inferences on the basis of the valid facts F1 ∪ F2 ∪…∪ Fi and possibly make hypotheses from the knowledge of Fi+1.



At the level of Fi there must be a compatibility among the facts F1 ∪ F2 ∪…∪ Fi, and the new facts that may have been deduced from this set are only valid at level i or below.

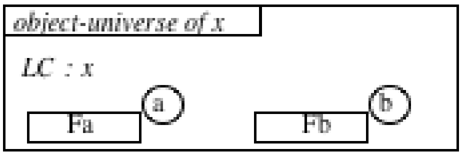
On the contrary we can have the following structure (where Fa(x) and Fb(x) are valid facts for their respective TZs) :



In this case, it is strictly impossible to compare or combine facts Fa(x) and Fb(x). As a matter of fact, they correspond to separated TZ. If we want to compare the two zones, we can only do it through *temporal* inferences, or by applying to them a general causation scheme of the world.

2.4 Comparing two pieces of information.

Let us now consider the case in which there is one single local constant about which we possess two pieces of information represented by two temporal zones a and b containing respectively the facts F_a and F_b. Besides, we suppose that we know nothing concerning the way the two zones are situated on a temporal point of view. Thus, we are in the following situation:

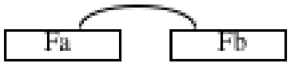


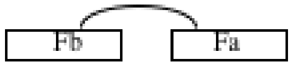
This situation may occur in different contexts. The main use of the reasoning scheme that we've got to present here is for understanding the continuity of a discourse. Thus, zone a can be an old element of knowledge that the system has about x and it should be linked with a new one coming from an utterance. Another case where it is important to compare two elements of knowledge on a temporal basis is when a question is asked concerning the constant x (for example "where is x?"). The meaning of such a question can be represented through a TZ that must be linked with the object-universe of x in order to find the adequate missing argument. We will not develop this aspect of the model in this paper.

If we desire to compare the two pieces of information above, it is necessary to list all possibilities, which will correspond to different hypotheses that the system will or will not validate. We can see that two elementary hypotheses can be contemplated:

<u>I. a and b are two separated zones.</u>

As seen before, no inferences can be done between facts Fa and Fb, but we have a more precise idea of their situation at the temporal level, so that we can construct two following sub-hypotheses :

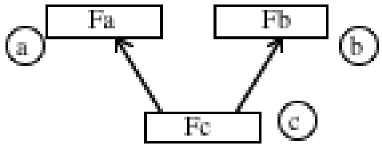
<u>I.1 a precedes b:</u> 

<u>1.2 b precedes a:</u> 

One of these two schemes can be validated by a typical structure in the world or by an explicit relation given by the discourse (for example, we can consider temporal anaphoras such as "then", "the day before" etc…)

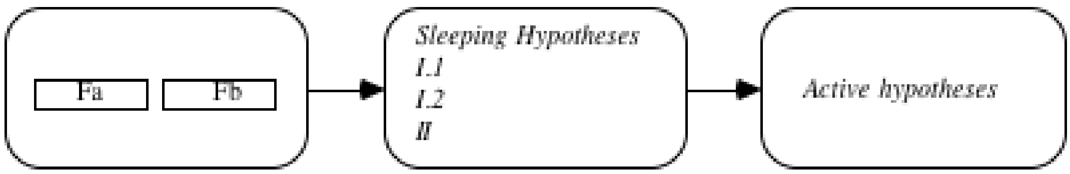
<u>II. a and b share a common temporal zone (under the inclusion relation).</u>

Consequently we can introduce the shared zone c (a result of the hypothetical reasonning) in order to produce the following scheme :



According to the propagation rule defined above, there will be an attempt to combine the valid facts Fa and Fb at the level of zone c : Fc = Fa ∪ Fb. This will be possible only if the set of facts Fc is coherent after the application of the different spatial rules defined.

So far, we have defined a way of creating a structure in which three different hypotheses cover the range of situations between two TZs. However, before using any of this hypotheses, one should be selected - or validated - by some external knowledge that we have about the world. Thus we call the hypotheses created *sleeping hypothesis*, and if one of them is validated it will then be called an *active hypotheses*. Thus, the general frame for the creation of a relation between two TZs is the following one :



Comparing two zones Creating hypotheses Validating hypotheses

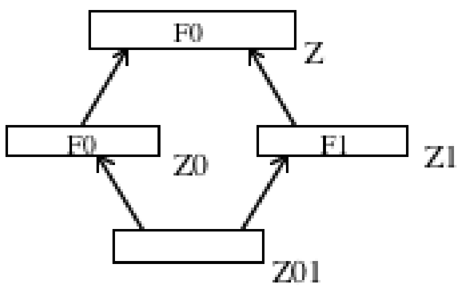
We can quote the following example to illustrate the passage of an hypothesis from the sleeping state to the active one :

Generalization rule *(on sleeping hypotheses)*:

Let Z_0 and Z_1 be two temporal zones with facts F_0 and F_1 such that:

- there exists a zone Z_{01} such that : (Z_{01} in Z_0) and (Z_{01} in Z_1)
- $F_1 := F_0$ (logical deduction, using propagation rules)

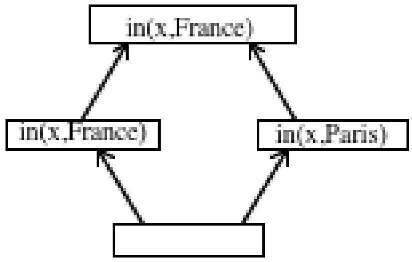
then create a zone Z with facts F_0 such that : (Z_0 in Z) and (Z_1 in Z).



Why do not we merge the two zones (for example when $F_0 = F_1$)? Because each of them holds its own links with a specific temporal context which mat not be compatible with the other one.

Example:

"x is in France", "x is in Paris", the hypothesis II gives the following result when we apply the generalization rule :



2.5 Implementation and examples.

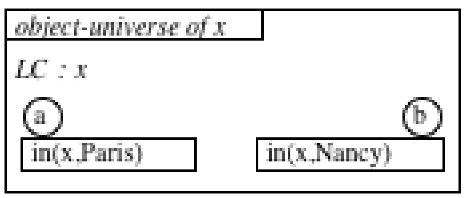
The several mechanisms presented have been implemented in common lisp to form an independent module that will be added to a syntactic-semantic analyzer on which we are working simultaneously. We will present two examples treated by this module. These examples show how useful it is to combine both a spatial and a temporal reasoning.

The first example below is a very simple one. It allows us to introduce two new concepts: *universal constants* and *universal facts*. Although these concepts should not appear in the plain theory, we introduce them here to facilitate the treatment of the examples. Universal constants are constants that do not appear in any temporal zone (though they should) and universal facts are spatial facts over universal constants, which can be used at any time if we apply the transition or incompatibility rules. In the following example we will need two UC : 'Paris' and 'Nancy' together with the UF : 'by(Paris,Nancy)'. Thus, if we adopt the notation of the preceding section, the example is characterized by :

Fa = { in(x,Paris) }

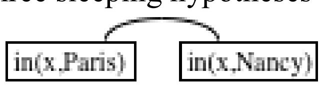
Fb = { in(x,Nancy) }

We have the following situation :

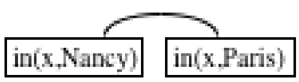


We can consider the three sleeping hypotheses :

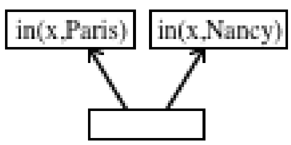
Sleeping hypotheses

I.1 

is OK

I.2 

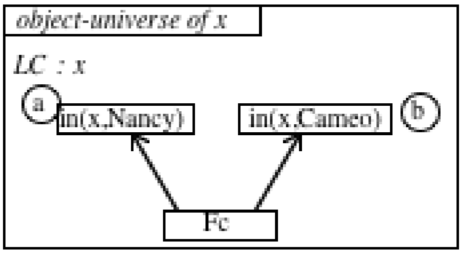
is OK

II 

is rejected because it generates a spatial inconsistency.

Effectively, hypothesis II generates the set of facts {in(x,Paris), in(x,Nancy), by(Paris,Nancy)} which is an inconsistent one.

On the contrary if we had the situation Fa = {in(x,Nancy)} and Fb = {in(x,Caméo)}, hypothesis II would have been accepted to build the following situation :

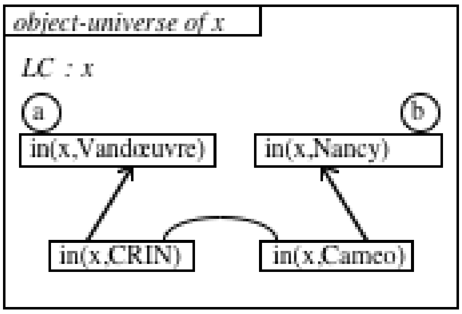


where - if we know the UF : 'in(Cameo,Nancy)' - the set Fc = {in(x,Nancy), in(x,Cameo), in(Cameo,Nancy)} is a consistent one. Moreover, we could apply the generalization rule to this last hypothesis in order to validate it.

We will now deal with a more complex example in which we observe that spatial and temporal inferences are complementary in order to determine the state of the world. Let us consider the following universal constants and facts:

- UC : 'Vandœuvre', 'Nancy', 'Cameo', 'CRIN'
- UF : in(CRIN,Vandœuvre), in(Cameo,Nancy), by(Nancy,Vandœuvre)

Suppose we have the following configuration about variable x:



As before there are three sleeping hypotheses to be considered :

Sleeping hypotheses
- I.1 is OK
- I.2 is rejected, because it generates a temporal inconsistency
- II is rejected, because it generates a spatial inconsistency.

As a result there is only one possible solution between zone a and b which form a coherent interpretation of the world. To achieve this result we need both the temporal and the spatial frame that cover a wider range of constraints when they are put together.

3. Two applications to natural language phenomena.

In this section, we present two topics in natural language understanding in which our model for time and space representation can be useful to keep a precise account of the meaning of a series of utterances. First of all, we will address the issue of the present tense to see how it works when it is used to describe the successive states of a scene. Then, we will see how we can represent changes in the world by means of a new proposal for the representation of events.

3.1 Scene description in the present tense.

The present tense has always been an awkward tense to represent since it does not seem to have a real temporal value. It can either refer to a period concomitant with the speech time or following it. In extreme cases (soccer report for example), it can even refer to a period in the near past.

A way to cope with this difficulty is to adopt the following rule for representing the meaning of predicates expressed in the present tense.

Present rule (*on sleeping hypotheses)* :

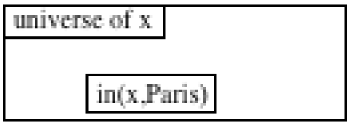
Any new temporal zone on constants x_1, x_2, … x_n resulting from the interpretation of a predicate P in the present tense must be considered as *the most recent piece of information* known about x_1,x_2, … x_n.

This means that, when they are compared with any previous information about x_1,x_2, … x_n, only hypotheses I.1 and II will be considered as valid.

This way of acquiring new pieces of information has already been proposed in works about the past tense, when Kamp (1983) proposed to use the temporal relation "not before" for successive sentences in that tense. As a matter of fact, our rule could be applied to a representation of past tenses. However, this would require us to introduce some specific concepts such as Reichenbach's Reference Point, which we can avoid if we limit ourselves to a strict present reference.

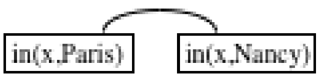
Simply, the effect of this rule above is to reduce the possibility of integration for a new piece of information. Thus, we can consider some examples of the way it works in real context.

Suppose we have two universal constants *Paris* and *Nancy* , the universal fact 'by(Paris,Nancy)' and a localized constant x about which we have no information at first. If we say "x is in Paris", we create a new TZ inside the universe of x representing the time when *x is in Paris*.

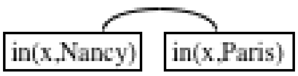


Then if the system is told : "x is in Nancy", a new TZ containing the fact 'in(x,Nancy)' is to be integrated in the universe of x. According to our schema of analyses, we can consider the three following hypotheses :

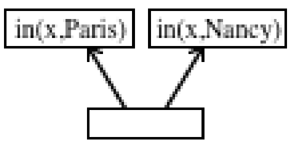
Sleeping hypotheses

I.1 

is OK

I.2 

is rejected (present rule).

II 

is rejected, because it generates a spatial inconsistency.

As a result, the only possible situation here is I.1 which becomes automatically active.

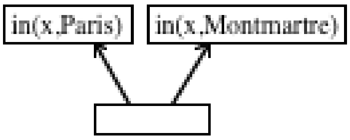
Another interesting case is when the new piece of information gives a more precise account of the situation described. Let us now consider the universal constants *Paris* and *Montmartre*, together with the universal fact 'in(Montmartre, Paris)', the localized constant x, and the first utterance "x is in Paris". Now, suppose that the system is told: "x is in Montmartre". We have the following situation:

Sleeping I.1 

is OK

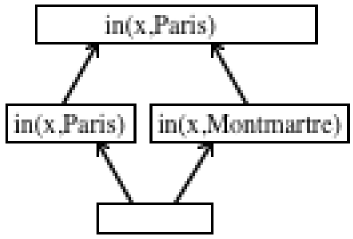
hypotheses I.2 

is rejected (present rule).

II 

is OK since no spatial inconsistency is generated.

At the end of this analysis, we obtain two sleeping hypotheses. However, the generalization rule can be applied to hypothesis II to make it active under the following schema:



It shows how new chunks of information in the present tense are easily acquired in our frame of analysis.

3.2 A quick look at events.

In many ontologies, events are specific objects differing from state by specific constraints on their temporal sub-structure. In that way, Allen introduces the following constraint:

occur(e,i) $\wedge$ [($\forall$ j) (j in i) => $\neg$occur(e,j)], {e : event, i j : intervals}

which means that an event such as "going to Paris" cannot occur in any sub-interval depending from the one on which the original event has been defined. But, in fact, these constraints do not give us the actual structure of the event and this is not the most amenable case in a knowledge representation perspective. On the other hand, research in computational linguistics has led to proposals concerning the structure of events. This is due to the fact that the semantic of tense and aspect especially cannot be considered if we do not make any difference between the moment of an action and its consequence, in order not to face some phenomena such as the famous imperfective paradox (Dowty 1977). Weber (1988) for instance introduced a three-fold structure : a preparatory phase, a culmination point and a consequent phase as follows :

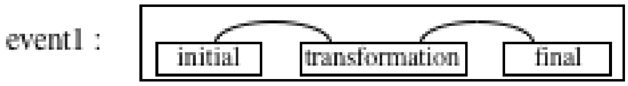
preparatory phase culmination consequent phase

——————————————||——————————————

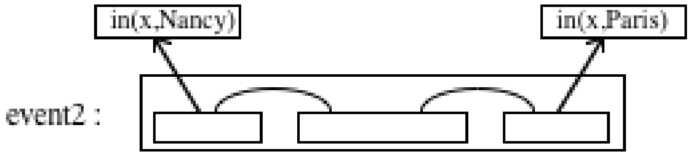
building a house *the house is completed* *he house exists*

The problem with this last structure is that the culmination point should actually be a point, whereas it is difficult to define exactly where this point is for any event. Another drawback of this structure is that it does not give anything concerning what preceeds the event. This is what we would need to understand "to go *from Nancy* to Paris".

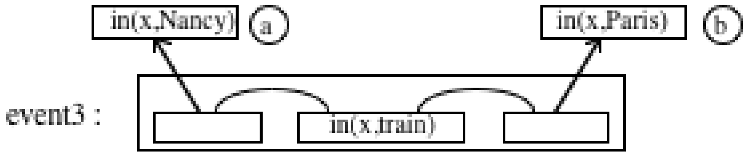
As a result, we propose a specific structure for events that is coherent with the general frame of analysis that we have been defining henceforth. An event is defined as a temporal zone which includes three sub-temporal zones, an initial zone, a transformation zone and a final zone, as below :



In order for both the initial and the final zone to be states from which and to which the transformation operates, each of them should be included in zones describing a general state of the world. Thus, "to go from Nancy to Paris" is represented by the following structure :

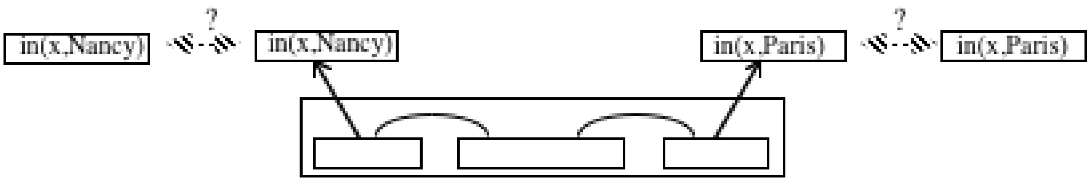


The transformation zone is actually a zone. This fact is important since it can contain facts that are stable all along the transformation. For example, if we learn that the going from Nancy to Paris has been done in a train, we could have:



Another important property of this structure is that it does not preclude the general states (zone a and zone b in the preceding schema) to overlap the transformation zone. For example, when you go from Paris to Nancy by train, you may still be in Nancy for a while after the departure of the train. If you want more information about the time when the leaving of Nancy occurs, you should have a representation of the transformation zone that is refined.

Our purpose here is not to show how this structure is adapted to the representation of many tenses and aspects in French or English. However, we can see that it can be used in the same way that we have used new pieces of information in the preceding section. Instead of comparing one single zone before and after an utterance, the introduction of an event in a knowledge base is done through the two general states of the world introduced above, as shown in the following schema.



This lets us to preserve the semantic we had proposed for the present tense, which is to give the most recent information about an object of the world.

4. Conclusions and prospects.

In this paper we have defined a reduced set of notions concerning the representation of time and space in a natural language context. The main points are that it seems possible to adopt a common framework to represent both notions and to define several rules that can be applied to combine different pieces of information. Still, there is a lot of work to be done to cover a larger range of concepts in order to apply this model to a real man-machine dialogue system. The main aspects that we have to study now are the articulation of our model with some general results about the semantic of time and tense, which could be seen as a front-end of a knowledge representation system based on the model we have just proposed. At the opposite corner, we are now working in specific pragmatic situations such as a dialogue with a speech editor, in which it is rather easy to define the main relations between the concepts of the world. We will consider that our model is validated as soon as it is possible to apply the same framework for knowledge representation in such a reduced application.

5. References

Allen James F. (1984), "Towards a general theory of action and time", *A.I. Journal*, pp.123-154.

Allen James F. & Hayes Patrick J. (1985), "A common-Sense Theory of time", *Proc. IJCAI 85*, 1985, pp.528-531.

Borillo M & Gaume B. (1990), "An extension to Kowalski & Sergot's event calculus", *Proc. of ECAI 90, Stockolm, Sweden*..

Borillo M. & Vieu L. (1989), "A comprehensive semantics of the spatial relation "dans" ("in")", *rapport IRIT, dec. 89*.

Carbonell N. & Pierrel J.M., "Architectures and Knowledge sources in a human-computer oral dialogue system", in *The structure of Multimodal Dialogue*, Taylor, Néel, Bouwhuis : eds, Elsevier, 1989.

Dowty David R. (1977), "Toward a semantic analysis of verb aspect and the English 'imperfective' progressive", Linguistics and Philosophy, Vol.1, pp.45-77, 1977.

Kamp H. & Rohrer C. (1983) "Tense in texts", in *Proceedings of the 1981 Linguistics Conference at Konstantz,* Germany, pp.250-269.

McDermott D. (1982), "A temporal logic for reasoning about processes and plans". *Cognitive Science,* Vol.6, 1982, pp.101-155.

Neumann B. (1989), "Natural language description of time-varying scenes", in D.L. Waltz ed., *Semantic structures, advances in natural language processing*, Lawrence Erlbaum, Hillsdale,N.J.

Ogihara T. (1989), *Temporal reference in English and Japanese*, Ph.D. dissertation, University of Texas, Austin.

Romary L. (1989a), *Vers la définition d'un modèle cognitif autour de la représentation du temps dans un dialogue homme-machine*, Ph.D. thesis, Université de Nancy I.

Romary L. et Pierrel J.M. (1989b), "Should a man-machine dialogue system be modular ?", Eurospeech 89, Paris, 26-28 sept., 1989.

Shoham Y. (1988), "Chronological Ignorance: Experiments in NonMonotonic Temporal Reasoning", *AIJournal,* Vol.36, pp.279-331.

Webber B.L. (1988), "Tense as discourse anaphora",*Computational Linguistics*, **14**, pp.61-73.9