# Modeling and Annotating the Semantics of Route Directions

Tomasz Marciniak and Michael Strube
EML Research gGmbH
Schloss-Wolfsbrunnenweg 33
69118 Heidelberg, Germany
http://www.eml-research.de/nlp

**Abstract**

In this paper we present our work on conceptual modeling and annotation of route directions. We analyze such texts as providing a description of *situations* involved in the dynamic conceptualization of a route. We develop an ontology of *situations* which is used as a reference for creating a semantic resource, i.e. a semantically annotated corpus.

## 1 Introduction

The primary function of an instructional discourse is to provide its recipient with enough information so that she can perform the task at hand. Such a text typically guides the recipient through various phases of the task by specifying a course of actions that one needs to take [1]. A specific sub-type of instructional texts considered here are navigational instructions, a.k.a. *route directions*. Texts from this category serve the purpose of informing the recipient how to find her way in an unknown environment.

The work reported in this paper is a part of a larger project concerned with generating natural language route directions. We focus on what constitutes the semantic or conceptual content of such texts. We recognize the fact that route directions do not describe the actual route in its static, physical sense but a range of *situations*, i.e. spatio-temporal interactions between the recipient of instructions and different elements of the route. The concept of situation is used here as the cover term for both motion actions that the recipient should undertake as well as peripheral events and states that *parameterize* the actions, i.e. provide initial and final conditions thereof. In route directions, descriptions of individual situations constitute major building blocks of a discourse, a.k.a. *discourse units*.

[1] For a discussion of *abstract instructions* that do not fit this model see (Stone, 2000)

The goals we realize in this paper are two-fold. We first construct an ontology of situations, i.e. a formal model capable of anchoring the semantic representation of route directions. This representation is used directly by our generation system as a specification of its input. In modeling situations we are not concerned with their *objective*, physical properties. Instead we take our ontology to specify a *conceptualization*, i.e. an abstract, and necessarily simplified view of the domain serving the purpose of representing actions, events and states with only as much specificity as is required for a navigational task (cf. (Gruber, 1995)). The main motivation for creating such a model comes from an analysis of the texts we focus on. The range of categories and properties that our model includes is directly inferable from the surface grammatical form of the linguistic expressions.

The second goal of our work is to create a *semantic resource*, i.e. a corpus annotated with semantic information, specifying the underlying conceptualization. The annotated corpus is used by our generation system as a source of *data* linking elements of the linguistic form, such as lexical and grammatical constructions, with conceptual structures they encode (see (Marciniak & Strube, 2004)). We view our approach as an alternative to constructing an *explicit* specification of such links, i.e. a lexicon (cf. e.g. (Stede, 1998)).

The annotation scheme that we use for this semantic tagging is based on the ontological specification, i.e. the tags correspond closely to the categories and properties defined in the ontology. One advantage of this approach is that the ontology can be used to *validate* human-made annotations, i.e. check for consistency with the formal model.

The paper is structured as follows: Section 2 introduces route directions and discusses the relations between the physical aspect of a route, the conceptual model of situations and the actual texts giving navigational instructions. In Section 3 we describe the ontology of situations, focusing on the major design decisions and their linguistic motivation. Finally, in Section 4 we show how the ontological model can be applied to semantic annotation of the route directions corpus.

# 2 From A Route to Route Directions

Instructional discourse can be analyzed at two different levels: *functional* and *conceptual*. At the functional level, we are concerned with how individual discourse units contribute to the overall purpose of an instructional text. This purpose typically involves a specification of a procedure that guarantees reaching the goal. Following (Denis, 1997) we can distinguish two general types of expressions that route directions typically contain, i.e. *prescriptions of actions* and *references to landmarks*. Prescriptions specify the actual actions that the route follower should take. References to topological elements of the route such as *paths* or *landmarks* may serve a number of different purposes, like marking locations where new actions should be taken, drawing attention to other less salient landmarks or providing confirmation that the right action is being carried out. At the conceptual level, instructional texts can be analyzed in terms of abstract entities that they describe. In the case of route directions we take these entities to be parts of a dynamic conceptualization of the route itself.

A route can be viewed in two different ways: statically, as a linear feature in the world defining a path between locations, and dynamically, as a process of following this path. In its static sense a route defines a path through some physical environment. This perspective concentrates on the physical aspects of a route, directly related to elements of the environment. These elements include linear entities such as streets or river sides that can define natural, physically discernible paths. Another category of route elements consists of landmarks located along the paths and typically restricted to limited portions of a route and decision points marking potential changes of direction or path (for more elaborate taxonomy and analysis of route elements see e.g. (Klippel, 2003)).

The dynamic analysis of a route focuses on the actual process of *route following*. Traditionally, this process has been considered to comprise a series of transitions or movements between subsequent decision points. Conceptualization of a route based on this transition model would thus mirror the functional level of route directions mentioned above: transitions between decision points can be seen as directly corresponding to the actions that the route follower is supposed to take.

A closer analysis of route directions (see Example 1) reveals however that they contain numerous references to different types of *situations* that do not necessarily constitute direct actions (e.g. 1a, c, d) of the route follower, nor can be always classified as transitions or movements (1a, d). We use the term *situation* to refer to both direct actions that the route follower is supposed to take (e.g. 1b, e) as well states (1a) and events (1c, d), in which she gets involved.

> **Example 1.** (a) Standing in front of the hotel (b) follow Meridian street south for about 100 meters, (c) passing the First Union Bank entrance on your right, (d) until you see the river side in front of you. (e) Then make a left onto North Hills Street.

In the domain of route directions, situations can be defined as schematic conceptualizations of spatio-temporal interactions between the route follower, and elements of the route. Linguistic realizations of individual situations provide further clues as to the kinds of relations holding between situations.

Since both situations and relations holding between them are conceptual entities *or abstractions* they do not represent processes taking place in the world in an objective way. In fact it is perfectly possible for one and the same route to be modeled dynamically in a number of different ways. First of all, not all the situations that one gets involved in while following a route need to be included in the conceptual model. The number of landmarks that the route follower may become aware of, and hence capable of *triggering* situations is usually much bigger than what is required by the functional criteria, as outlined at the beginning of this section. Secondly, once a set of situations has been selected, a temporal structure needs to be imposed upon them. As we shall show in the next section, it is often possible to structure the same group of situations in a number of ways. Again it is the functional criteria that play the decisive role.

# 3 Situations Ontology

The ontological model that we present in this section is an attempt to capture the relevant entities in the domain of route following. In this domain we are mostly concerned with interactions that take place between the follower of a given route and salient elements of her environment, i.e. the landmarks. We take the position that conceptualizations of these interactions, that we refer to as situations, constitute the semantic content of an instructional text. We further view semantic interpretation of such a text as a task of constructing a conceptual representation of the individuals that the text describes.

The ontology comprises two elements: a taxonomy of relevant concepts and a set of axioms. The concepts represent a range of situations that the process of route following involves, their properties and relations that may hold between them. The role of axioms is to constrain possible interpretations and specify well-formedness conditions [2].

## 3.1 Different Perspectives

Situations can be analyzed from different conceptual angles. Following (Reichenbach, 1948) we can first consider two basic dimensions referred to as *event splitting* and *thing splitting* perspectives. The former one is concerned with the internal temporal stages that a situation consists of, which determine its *aspectual type*. From the *thing splitting perspective*, a situation is viewed as a collection of individuals which are assigned thematic roles specifying their relations to one another. By adopting basic principles of Fillmore's *frame semantics* (e.g. (Fillmore, 1977)) we can further think of situations as falling into different *categories of experience*, such as *self-motion* or *visual perception* each associated with its own subset of conceptual roles. In the following we will use the term *frame structure* to denote this experience-related profile.

Finally, we recognize the fact that situations are not conceptualized in isolation, but in larger groups, having a specific temporal structure. This structure is based on a set of binary relations holding between individual situations. In the context of route directions we are concerned mostly with temporal relations, which specify the relative positions of situations with respect to one another.

A major design decision that we adopted in creating the ontology of situations was to hold these different dimensions separate at the taxonomic level and relate them only at the level of axioms.

[2] The ontology has been specified in the OWL-DL ontology language which offers reasoning facilities of *Description Logics* (see e.g. (Baader et al., 2002))

### 3.2 Aspectual Structure

Traditionally, aspectual types have been considered to be properties of verbs. Both (Vendler, 1967) and (Kenny, 1963), who proposed their own taxonomies, devised grammatical tests allowing appropriate classifications of verbs.

In the current work we attribute aspectual categories to situations that linguistic expressions describe and not the expressions themselves. First of all, as observed for instance by (Mourelatos, 1978), the aspectual analysis often depends on the semantic arguments present in the clause, and not just the verb, e.g.: *Walk down the street* vs. *Walk down the street to the intersection* vs. *Walk inside the building*. Aspectual analysis can be also applied to situations which are described by expressions containing no verbs, e.g. *Down the street, past the post office and then left*. Finally, we can think of non-linguistic means to refer to situations that also allow discrimination of aspectual types (e.g. (Tversky & Lee, 1999)).

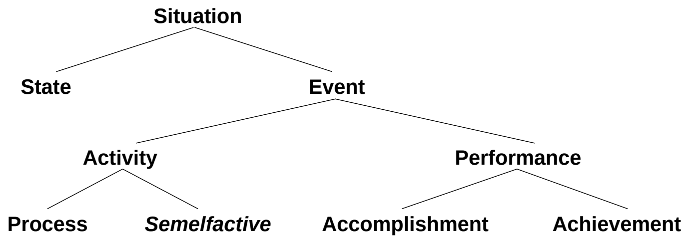


Figure 1: Taxonomy of aspectual types of situations

The taxonomy of aspectual categories, that we adopted is presented in Figure 1. It is based on the four classes proposed by Vendler, i.e. *states*, *activities*, *accomplishments* and *achievements*, with minor extensions borrowed from (Kenny, 1963) and (Bach, 1986). Following (Moens & Steedman, 1988) we can define each aspectual category with respect to three aspectual attributes: *stative*, *durative* and *culminated*. Respective intensional definitions are given below.

$$\forall x(State(x) \leftrightarrow Situation(x) \wedge isStative(x))$$
$$\forall x(Event(x) \leftrightarrow Situation(x) \wedge \neg isStative(x))$$
$$\forall x(Activity(x) \leftrightarrow Event(x) \wedge \neg isCulminated(x))$$
$$\forall x(Process(x) \leftrightarrow Activity(x) \wedge isDurative(x))$$
$$\forall x(Semelfactive(x) \leftrightarrow Activity(x) \wedge \neg isDurative(x))$$
$$\forall x(Performance(x) \leftrightarrow Event(x) \wedge isCulminated(x))$$
$$\forall x(Achievement(x) \leftrightarrow Performance(x) \wedge \neg isDurative(x))$$
$$\forall x(Accomplishment(x) \leftrightarrow Performance(x) \wedge isDurative(x))$$

A situation can now be assigned to a particular category on the basis of the aspectual attributes that it carries. Consider a fragment of an instructional text in Example 2 below.

**Example 2.** (a) Facing the Wildcat statue, (b) turn left on the brick sidewalk (c) and continue along the road to the Sports Complex.

(d) Make a right onto Concord Road, (e) and keep going straight, (f) passing Presbyterian Church on your left, (g) until you reach Copeland Street. (h) The library building will be just around the corner on your right.

The attribute *stative* allows to differentiate between *States* (2a, h) and *Events*. A *State* can be informally defined as a situation, in which the profiled entity is attributed an unchanging property, e.g. a *location*. *Events*, on the other hand, are situations involving explicit or implicit change of state, as in the case of motion or perception. Another attribute, *culminated*, allows to distinguish two subclasses of *Events*[3] : *Activities* (2e) and *Performances* (2b, c, d, f, g). An *Activity* has no culmination point and can be terminated at any time. If that happens we cannot be sure what the current state is, and cannot locate another situation within this state. A *Performance* on the other hand is always *culminated* which implies that it results in some well-specified state. We can then think of another situation (e.g. 2h) as being bound to (or *dependent on*) this state. Finally, the *durative* attribute specifies whether an *Event* is conceptualized as extended in time or punctual. Applied to *Performances*, it allows a distinction between *Accomplishments* (2c, f) and *Achievements* (2b, d, g). In the domain of motion events *Activities* are typically durative and we label them as *Processes*. *Semelfactives*, i.e. non-durative *Activities*, denote punctual occurrences with no culmination, and can form *iterative processes*.

### 3.3 Frame Structure

In our domain, the three most frequent experiential categories are *SelfMotion*, *Localization* and *VisualPerception* [4]. Each of them is modeled as a frame, with slots specifying conceptual roles attributed to situation participants. For a frame to be complete, only some of its roles need to be filled. In the case of *SelfMotion*, for instance, only the *self_mover* role must be instantiated. Notice, however, that not all participants of a given situation need to be mentioned in its linguistic description. In imperative clauses, for instance, the agent or *self_mover* role is typically omitted. Similarly, in expressions like *Leave!* or *Walk in*, the *source* and *goal* roles are respectively implicit. An overview of roles associated with each category is presented in Table 1.

| *Frame* | *Conceptual Roles* |
|---|---|
| SelfMotion | self_mover, source, path, goal, direction, distance, duration |
| VisualPerception | perceiver, perc_object, direction, distance, location |
| Localization | located_object, direction, distance, location |

Table 1: Frames with corresponding conceptual roles

[3]By default, States are considered *not culminated* and *durative*

[4]The categories are partially based on the FrameNet frames, with conceptual roles corresponding to frame elements (cf. (Baker et al., 1998))

| *SelfMotion Roles* | *Relations* |
|---|---|
| *source* | *OUT_OF, FROM* |
| *path* | *ACROSS, PAST, ALONG* |
| *goal* | *TO, INTO, ONTO, TOWARDS* |
| *direction* | *RIGHT, LEFT, NORTH, WEST, SOUTH, EAST* |

Table 2: Relations associated with conceptual roles of *SelfMotion* frame

Conceptual roles can be either *relational* or *primitive.* A relational role links a situation participant with a role-specific relation. A primitive role, on the other hand is associated with a situation participant only. Consider expression (g) from Example 2:

(g) until you reach Copeland Street

Both *you*[5] and *Copeland Street*[6] participate in a *SelfMotion* situation, and are assigned the roles of *self_mover* and *goal* respectively. *Self_mover* is a *primitive* role since no specific relation can be attributed to its filler. Other primitive roles include *perceiver, located_object, distance* and *duration. Goal* on the other hand is considered *relational*, i.e. the situation participant *Copeland Street* is linked to spatial relation *TO.* Other roles, such as *source, path, direction* or *location* also fall in this group.

For each relational role we can specify a set of specific relations (see Table 2 for *SelfMotion* roles). These relations can be further analyzed using the same set of aspectual attributes that we applied to situations (cf. (Jackendoff, 1983)). Hence *ALONG* can be characterized as *durative* and *not culminated* whereas *TO* is both *durative and culminated.* We can now notice a correlation between the aspectual profile of a situation and the kinds of relations associated with some of its roles. Expression (c) from Example 2, for instance, describes a *SelfMotion* situation with a *durative* path and *culminated* goal. We can conclude that the whole situation also possesses these properties. Examples of corresponding rules are given for the SelfMotion frame, which can be formulated as follows:

$$\forall s(\exists f, p(Situation(s) \wedge SelfMotion(f) \wedge Path(p) \wedge hasFrame(s, f) \\ \wedge\ hasPath(f, p) \wedge\ isDurative(p)) \rightarrow isDurative(s))$$

$$\forall s(\exists f, g(Situation(s) \wedge SelfMotion(f) \wedge Goal(g) \wedge hasFrame(s, f) \\ \wedge\ hasGoal(f, g) \wedge\ isDurative(g)) \rightarrow isDurative(s))$$

$$\forall s(\exists f, p(Situation(s) \wedge SelfMotion(f) \wedge Path(p) \wedge hasFrame(s, f) \\ \wedge\ hasPath(f, p) \wedge\ isCulminated(p)) \rightarrow isCulminated(s))$$

$$\forall s(\exists f, g(Situation(s) \wedge SelfMotion(f) \wedge Goal(g) \wedge hasFrame(s, f) \\ \wedge\ hasGoal(f, g) \wedge\ isCulminated(g)) \rightarrow isCulminated(s))$$

[5]Identified as the route follower

[6]A specific route element

### 3.4 Temporal Structure

Temporal structure of a group of situations is based on a set of temporal relations holding between individual situations. We draw a distinction here between *absolute* relations which specify the ordering of situations along a time scale, and *relative* relations reflecting a particular conceptualization.

To specify the absolute ordering we use three binary relations: *precedes*, *follows* and *overlaps*. For each pair of situations, $s_1$, $s_2$ it holds that either $s_1$ *precedes* $s_2$, $s_1$ *overlaps* $s_2$, or $s_1$ *follows* $s_2$, where *precedes* is inverse of *follows*, *overlaps* is symmetric and all three are transitive. At the conceptual level, on the other hand, a relation always reflects a particular perspective (or *vantage point*) from which a pair of situations is considered. We first notice that the status of two situations within a profiled relationship is not equal. For each pair of such related situations we distinguish between the *landmark situation* serving as a reference point and the *trajector situations* whose temporal location is considered [7].

Depending on its aspectual category, each situation can be associated with up to three temporal intervals: *initial, subsequent* and *ongoing*. The *initial* phase can be applied to an *Event* only and it denotes the period immediately preceding its onset. In the case of *Performances*, the culmination point results in what can be referred to as a *subsequent* stage. Finally, situations which are durative, i.e. *States*, *Processes* and *Accomplishments* possess an *ongoing* stage.

A temporal relation holding between situations $s_1$ and $s_2$ can now be defined as a specification of the temporal interval of $s_1$, identified as a landmark, during which $s_2$, identified as the trajector, takes place. Three types of such relations, related to the respective intervals, are labeled as: *initialRel*, *ongoingRel* and *subsequentRel*. All three relations are functional, i.e. a given situation can figure as a trajector in one relation only. Also, none of the relations has an inverse one, i.e. for a pair of related situations only one trajector-landmark alignment is possible. The respective well-formedness conditions are specified below:

$$\forall s_1, s_2(initialRel(s_1, s_2) \rightarrow Situation(s_1) \wedge Event(s_2) \wedge overlaps(s_1, initial(s_2))$$
$$\forall s_1, s_2(subsequentRel(s_1, s_2) \rightarrow Situation(s_1) \wedge Performance(s_2) \wedge overlaps(s_1, subsequent(s_2))$$
$$\forall s_1, s_2(ongoingRel(s_1, s_2) \rightarrow Situation(s_1) \wedge (Process(s_2) \vee Accomplishment(s_2)) \wedge overlaps(s_1, ongoing(s_2))$$
$$\forall s_1, s_2(related(s_1, s_2) \rightarrow \neg\exists s_3(related(s_1, s_3)))$$
$$\forall s_1, s_2(related(s_1, s_2) \rightarrow \neg related(s_2, s_1))$$

We can now apply the three relations to analyze the temporal structure of the situations described in Example 2. Consider expressions (a) and (b):

(a) Fac*ing* the Wildcat statue, (b) turn left on the brick sidewalk

[7] Terms *vantage point*, *landmark* and *trajector* are used in the sense proposed by (Langacker, 2000)

First we must assign *trajector* and *landmark* roles to the respective situations. Since expression (a) bears a linguistic *marking* (i.e. gerund form) signaling the relation, we consider the situation that it describes to be the trajector. We can then conclude that situation denoted by (a) stands in a *initialRel* relation to the one in (b), *initialRel(a, b)*, i.e. situation in (a) is bound to the *initial* stage of (b). Notice that in absolute terms we might both relate (a) to (b), i.e. *precedes(a, b)* and (b) to (a), i.e. *follows(b, a)*.

Similarly, we can analyze another pair of expressions from Example 2:

> (d) Make a right onto Concord Road, (e) *and* keep going straight

as being structured in the following way: *subsequentRel(e,d)*. This time it is the discourse connective that signals the relation. In cases where no explicit marking is present, e.g.:

> (c) ... continue along the road to the Sports Complex. (d) Make a right onto Concord Road,

we can assume *default* temporal interpretation (c.f. (Lascarides & Asher, 1993)), and locate situation in (d) in the subsequent stage of that in (c): *subsequent-Rel(d, c)*.

## 3.5 Representing Individual Situations

Finally, the categories described in this section can be put together to represent individual situations described in an instructional text. Consider discourse units (d) and (c) from Example 2. The conceptual structure of the situations they describe, is presented in Figure 2.

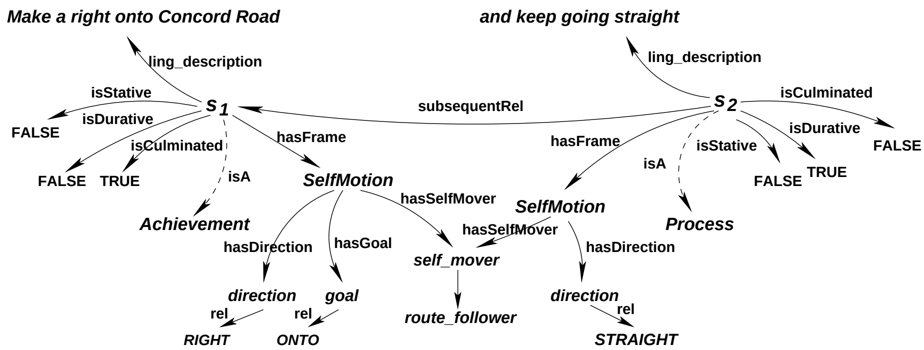


Figure 2: Representation of situations $s_1$ and $s_2$ described by a pair of discourse units: *Make a right onto Concord Road and keep going straight.*

| ***Ontological Level*** | ***Semantic Tags*** | ***Markable Level*** |
|---|---|---|
| *Aspectual Structure* | *stative, durative, culminated* | *Discourse-unit* |
| *Frame Structure* | *self_motion, visual_perception, localization* | *Discourse-unit* |
| | *self_mover, source, path, goal, direction, ...* | *Argument* |
| *Temporal Structure* | *trajector, landmark* | *Discourse-unit* |
| | *initialRel, ongoingRel,subsequentRel* | *Discourse-unit* |

Table 3: Annotation Scheme

| **Frame Str.** | **Freq.** | **Aspect. Str.** | **Freq.** | **Temp. Str.** | **Freq.** |
|---|---|---|---|---|---|
| *self_motion* | 729 | *stative* | 129 | *initialRel* | 92 |
| *localization* | 104 | *durative* | 432 | *ongoingRel* | 235 |
| *vis_perception* | 42 | *culminated* | 539 | *culminatedRel* | 481 |

Table 4: Frequencies of attributes at different levels

## 4 Annotation and Semantic Representation

Our corpus of route directions consists of 70 texts with a total number of 857 discourse units providing descriptions of individual situations. The texts were obtained from printed tourist guide books or found on the Internet. The annotations comprise *markables*, i.e. marked text spans, falling in four different categories. *Discourse-unit* markables relate to individual situation descriptions, realized as single clauses. Within clauses main verbs were tagged as *Predicate* markables and the arguments of verbs as *Argument* markables. Finally, conjunctions and discourse markers were labeled as *Discourse-connectives*.

In order to apply the ontological model of situations to the task of annotating route directions we defined an annotation scheme comprising a selection of semantic tags which provide a flat representation of the classes and properties from the ontology (consider Table 3).

Annotations have been realized at different levels, corresponding to the levels specified in the ontology. At the *aspectual* level each *Discourse-unit* markable has been assigned three boolean attributes: *stative, durative* and *culminated*. At the *frame structure* level *Discourse-unit* markables have been tagged with frame labels (i.e. *self_motion, localization, etc.*) and *Argument* markables have been assigned semantic roles (e.g. *source, path* or *goal*). Finally, at the *temporal structure* level, pairs of *Discourse-unit* markables corresponding to related situations have been respectively tagged as *trajector* and *landmark* and linked by a directed relation carrying a specific label (i.e. *initialRel, ongoingRel* or *subsequentRel*). The three levels of annotation are presented in Figure 3. In Table 4 we provide frequencies with which respective attributes were assigned to the corresponding markables.

Finally, the attributes defined in the annotation scheme can be used to represent the semantic content of route directions. We first take the discourse structure of such a text to correspond to the temporal structure of the profiled

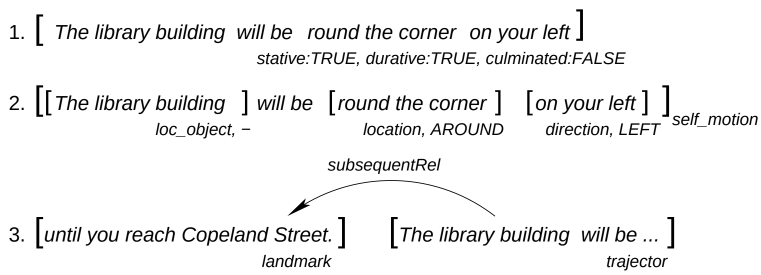


Figure 3: Three levels of annotation: 1. *Aspectual Structure*, 2. *Frame Structure*, 3. *Temporal Structure*

situations. We represent it as a *tree*, with nodes corresponding to individual discourse units and edges signaling *trajector-landmark* relationships (see Figure 4). Semantic content of individual discourse units can be further denoted by *aspectual* and *frame structure* attributes.

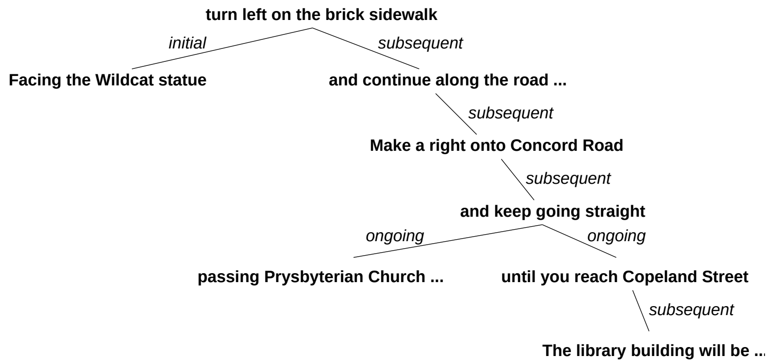


Figure 4: Temporal Structure

# 5 Conclusions

In this paper we took the position that route directions describe not the route itself but its dynamic conceptualization structured in terms of temporally related situations. The ontology of situations that we built was then applied to analyze and annotate the semantic structure of a corpus of route directions. We used thus created resource in our generation system that produces route directions and consider its application for other NLP tasks such as analysis and summarization of instructional texts.

**Acknowledgements:** The work presented here has been funded by the Klaus Tschira Foundation, Heidelberg, Germany. The first author receives a scholarship from KTF (09.001.2004).

# References

Baader, F., D. Calvanese, D.L McGuinness, Nardi D. & P.F Patel-Schneider (Eds.) (2002). *The Description Logic Handbook: Theory, Implementation and Applications.* Cambridge University Press, Cambridge, UK.

Bach, Emmon (1986). The algebra of events. *Linguistics and Philosophy*, 9:5–16.

Baker, Collin F., Charles J. Fillmore & John B. Lowe (1998). The Berkeley FrameNet project. In *Proceedings of the 17th International Conference on Computational Linguistics and the 36th Annual Meeting of the Association for Computational Linguistics,* Montréal, Québec, Canada, 10–14 August 1998, pp. 86–90.

Denis, Michel (1997). The description of routes: A cognitive approach to the production of spatial discourse. *Current Psychology of Cognition*, 16:409–458.

Fillmore, Charles (1977). The need for a frame semantics in linguistics. *Statistical Methods in Linguistics*, 12:2–29.

Gruber, Thomas R. (1995). Toward principles for the design of ontologies used for knowledge sharing. *International Journal of Human-Computer Studies*, 43(5-6):907–928.

Jackendoff, Ray S. (1983). *Semantics and Cognition.* MIT Press, Cambridge, MA.

Kenny, Anthony (1963). *Action, Emotion and Will.* Humanities Press, New York.

Klippel, Alexander (2003). Wayfinding choremes. In Werner Kuhn, Michael F. Worboys & Sabine Timpf (Eds.), *Spatial Information Theory. Foundations of Geographic Information Science*, pp. 301–315. Springer, Berlin.

Langacker, Ronald W. (2000). *Grammar and Conceptualization.* Cognitive linguistic research 14. Mouton de Gruyter, Berlin, New York.

Lascarides, Alex & Nicholas Asher (1993). Temporal interpretation, discourse relations, and common sense entailment. *Linguistics and Philosophy*, 9:83–95.

Marciniak, Tomasz & Michael Strube (2004). Classification-based generation using TAG. In *Proceedings the 3rd International Conference on Natural Language Generation, INLG 2004, Brockenhurst, UK, 14-16 July 2004*, pp. 100–109.

Moens, Marc & Mark Steedman (1988). Temporal ontology and temporal reference. *Computational Linguistics*, 14(2):15–28.

Mourelatos, Alexander P. D. (1978). Events, process, and states. *Linguistics and Philosophy*, 2:415–434.

Reichenbach, Hans (1948). *Elements of Symbolic Logic.* Macmillian, New York.

Stede, Manfred (1998). A generative perspective of verb alternations. *Computational Linguistics*, 24(3):401–430.

Stone, Matthew (2000). Towards a computational account of knowledge, action and inference in instructions. *Journal of Language and Computation*, 1(2):231–246.

Tversky, Barbara & Paul E. Lee (1999). Pictorial and verbal tools for conveying routes. In Christian Freksa & David M. Mark (Eds.), *Spatial Information Theory: Cognitive and Computational Foundations of Geographic Information Science*, pp. 51–64. Springer, Berlin.

Vendler, Zeno (1967). Verbs and times. In *Linguistics in Philosophy,* Cornell University Press, Ithaca, NY: chap. 4, pp. 97–121.