Abstract

Cross linguistic study of motion verbs and the notion of semantic primes point in the direction of semantic components of motion representations in language. This paper aims to outline the semantic link between Qualitative Spatial Representations (QSR) of spatio-temporal change and linguistic expressions of the same. Reasoning about such QSR based spatial processes is based on axiomatic specifications whereas such reasoning in linguistics is mainly based on entailment and causal relations between action verbs of motion. We examine linguistic reasoning about spatio-temporal processes and compare these to axioms in QSR. Some future directions of research in this area are outlined.

1 Introduction

Motion verbs provide linguistic representation of spatial change and evidence for human reasoning of spatial change through language can be seen in [Jackendoff, 1983]. Perhaps verbs occur in English sentences as the most important critical component of sentence meaning and completeness. It denotes the notion of process, action or activity and also has a temporal component (tense). There are also verbs which have some intrinsic spatial meaning. These include motion verbs and existence verbs\(^1\) such as {move, fly, drag, pull} and {appear, locate, remain}. For reasons explained in the footnotes we chose to focus on the former category of verbs in our venture of studying spatial verbs.

So what is special about spatial verbs? And are there purely “spatial” verbs? The answer is negative. Spatial verbs are spatio temporal verbs and do not exist in isolation. We discuss cross linguistic classification of such verbs in this section and present evidence of semantic components in linguistic representations of spatio-temporal change. In the subsequent section we discuss aspects of QSR which relate to the semantics of spatial verbs. The third section discusses entailment relations in spatial verbs and its relation to entailment relations in axiomatic statements of spatial change in QSR. Finally we conclude with a summary and scope of future work.

1.1 Motion verbs

Zlatev [1997] presents seven spatial semantic categories which include Trajector, Landmark, Motion, Frame of Reference, Region, Path, and Direction. These categories help to further restrict our discussion to a smaller area which we choose to define as object and person trajectories bound to Ground and Relative Landmarks. We choose cases of perceived motion in allocentric, and deictic reference frame. It is important to note that English mostly uses the deictic verbs [Fellbaum, 2002].

1.2 Semantics of motion complexes

Motion verbs have been widely studied, as compared to other classes of verbs classified by Levin [1993]. Asher and Sablayrolles [1994a] have discussed French intransitive verbs to evolve a further classification into Change of Location verbs (\textit{entrer}), Change of Position verbs (\textit{voyager}, \textit{courir}) and Change of Posture verbs (s’ \textit{asseoir}). Of these, Change of Position verbs can be subdivided into verbs that surely denote a change of position and others which merely indicate a possibility. Asher and Sablayrolles [1994b] discusses a complex formal calculus for motion complexes (verbs with prepositions) to obtain their semantics.

However verbs of spatial configuration, lodge verbs, avoidance verbs and occurrence verbs have strong relevance in motion representation. These classifications are not formalized as compared to Sablayrolles [1995], Landau and Jackendoff [1993] both of which have a similar notion of classification of motion based on the motion starting, path and final positions. This is done primarily on the basis of partition of space into inside, external zone of contact and outside. Landau and Jackendoff [1993] use such structuring for static spatial prepositions. The most significant impact of such structures can be seen in the inferences about space in Lexical Conceptual Structures (LCS) [Jackendoff, 1990]. Conceptual structures assume the possibility of motion or the lack of it, to define a spatial structure in language based on spatial intuitions. (Further discussed in section 2.3)

\(^1\) The “to be” verb can also be argued as an existence verb but is used in great variety of ways including “is at” or “is a part of” relations. While some of these can be spatial it becomes difficult to dissociate metaphorical extensions of the spatial case.
2 Semantics of motion in linguistic representation

Spatial verb-preposition classification studies can be done to derive concepts of motion. These include notions of actions and affordances. We investigate some of the underlying principles towards formation of such components.

2.1 Action

Actions in the context of motion have been previously discussed to have both verb and preposition components. As discussed by Fellbaum [2002], some types of languages (like Germanic, Chinese) conflate “fact of motion” and manner while some others (Romance, Greek, Semitic) conflate “fact of motion” and path. It is also discussed that there is greater salience for the path element in the domain of motion verbs and that path could be omitted only in cases where the activity had no explicit end state.

Japanese is reported to have mostly path encoded simplex motion verbs besides compound verbs which encode both manner and path [Matsumoto, 1996]. He also shows similarity with English in the context of the necessity of path component for unless there is a subjective usage of verbs. He concludes that since these two languages are genetically unrelated, the need of component of path component for verbs of subjective motion has elements of cognitive truth. Aceland et al [2004] have discussed that directionality cannot be removed from either the verb or its prepositional part in a motion complex. This suggests that directionality or path component is one of the primitives of motion representation and is consistent with the observation about discussed above.

The table below shows action concepts and semantic primes using action and space components [Goddard, 2002]. The only spatial action prime move is combined with do and happen to obtain six classes of verbs with the five classifications for space. The existence component there is can also be used similarly. We have not attempted the negations of these 20 categories which would result in 40 more categories only because negative verbs (antonyms of the corresponding verbs in table below do not necessarily exist although this can be attempted in future.

2.2 Affordances

Affordance forms of verbs like “Jumpable”, “Walkable” or based on the property of an object to afford a certain kind of action can be called as affordances as per Gibson’s notion affordance [Gibson, 1979]. To borrow ideas from ecological psychology for spatial reasoning and agent based wayfinding is not new in the spatial domain [Raubal, 2003].

Although there is no basis for affordances in linguistics since the word itself has been claimed to be ‘made up’ by Gibson, we can classify existing spatial adjectives if they can serve as affordances. This means one could use the verb forms of such affordances to align these verbs-preposition complexes such as

- Jump-on, Jump-in, Jump-over, Jump-off
- Walk-on, Walk-in, Walk-over, Walk-through

Affordances are however, measurable and are not deterministic. An affordance value can range between null to cent percent. Unlike Actions which indicate fact, affordances only indicate a possibility.

2.3 Constraints of motion representation.

Three important components of representation of motion have been seen which are:

Direction, manner of motion

Direction of motion or the path component is required to convey any kind of motion. Similarly the degree of motion (speed) can also be considered essential although the default case of movement (which is go in the LCS theory [Jackendoff, 1990] and move in the case of semantic primes [Goddard, 2002] is sufficient.

States

The existence of final events can be seen in the example of achievement verbs such as reach or arrive. Such verbs have a state which can be defined in the notion of reached and arrived respectively as discussed in Fellbaum [2002]. Such states are not necessarily instantaneous.

Entailment and Causal structure

Entailment [Fellbaum, 1998] explores hierarchies of verbs and motion verbs. The following types of entailments have been discussed.

- Troponymy: v1 is v2 in some manner (e.g., speeding entails driving) – this corresponds to the subconcept-superconcept relation for objects;
- Proper inclusion: v1 and v2 occur together, but not for the entire duration (e.g., passing entails swerving) – this corresponds to the part-whole relationship for objects, but the inclusion can occur in either direction;
- (Backward) presupposition: v2 precedes v1 (e.g., driving on a road entails entering it);

<table>
<thead>
<tr>
<th>Primes</th>
<th>Here/Where</th>
<th>Above/Below</th>
<th>Far/Near</th>
<th>Side</th>
<th>Inside</th>
</tr>
</thead>
<tbody>
<tr>
<td>Move</td>
<td>visit, go,</td>
<td>jump, fall</td>
<td>Migrate</td>
<td>Skirt</td>
<td>Enter</td>
</tr>
<tr>
<td>Do (Move)</td>
<td>Move (something)</td>
<td>Fly (something)</td>
<td>Throw, push</td>
<td>push aside</td>
<td>Pull</td>
</tr>
<tr>
<td>Happen (move)</td>
<td>(something) moves</td>
<td>(something) flies</td>
<td>(something) shifts</td>
<td>(something) gets moved</td>
<td>(something) enters</td>
</tr>
<tr>
<td>There is</td>
<td>be, is, exists</td>
<td>Covered, floored</td>
<td>Removed</td>
<td>Borders, encircles</td>
<td>Contained</td>
</tr>
</tbody>
</table>

Table 1 Categories of actions based on semantic primes
• Causation: $v_1$ causes $v_2$ (e.g., being passed causes one to control the speed).

2.3 Spatial intuitions.

Jackendoff [1990] states some spatial intuitions for conceptual structures. These are:

• If someone stays at someplace for a period of time, he is in that place at any instant during that time.

\[ \text{STAY(THING,a[t_1,t_2])} \Rightarrow \text{BE(THING,a,t_3)} \quad \text{such that } t_1 \leq t_3 \leq t_2 \]

• If someone doesn’t stay at someplace during an interval, there is a time during the interval he isn’t there.

\[ \neg \text{STAY(THING,a[t_1,t_2])} \Rightarrow \neg \text{BE(THING,a,t_3)} \quad \text{such that } t_1 \leq t_3 \leq t_2 \]

• If and only if someone is at someplace he is somewhere else.

\[ \neg \text{BE(THING,a,t_1)} \Rightarrow \text{BE (THING,b,t)} \text{ where } a \neq b \]

• If and only if someone is at someplace he is not elsewhere.

\[ \text{BE(THING,a,t_1)} \Rightarrow \neg \text{BE(THING,b,t)} \text{ where } a \neq b \]

• If something goes from one place to another it was at the first place first and the second place second.

\[ \text{GO (THING,}[a,b],t_1,t_2] \Rightarrow \text{BE(THING,}a,t_1) \text{ } \text{BE(THING,}a,t_2) \quad \text{such that } t_1 \leq t_2 \]

• If you are going someplace you are not staying anywhere and if you staying someplace, you aren’t going anywhere.

\[ \text{GO (THING,}[a,b],t_1,t_2] \Leftrightarrow \neg \text{STAY(THING,a[t_1,t_2])} \]

These intuitions serve as constraints on spatial action concepts in language.

3 Logical Representations

In this section we briefly look at the qualitative representations of spatial change. Such representation and its axioms are compared to the principles in the previous section.

3.1 Qualitative Representations of spatial change

Qualitative spatial representation (QSR) [Freksa, 1991] of motion provides a model of representation of spatio-temporal change. Weghe et al [2004] illustrate the use of transitions between RCC relations assuming continuous motion. This would allow to model stative verbs and process verbs under a qualitative framework. QSR assumes relative motion and hence the existence of relative frame of reference is necessary which makes some interpretation in Deictic verbs [refer section 2 discussion of universal semantic categories Zlatev [1997]]. The first object in “The Car moves.” is assumed to be the speaker and hence this represents $(0+0)$ in the Qualitative trajectory calculus along a Road network (QTCN). We present some verbal equivalents of the QCTN along with sentences in the table below.

<table>
<thead>
<tr>
<th>QTCN Rep.</th>
<th>Verbs</th>
<th>Usage in sentence</th>
<th>Action representation</th>
</tr>
</thead>
<tbody>
<tr>
<td>(00)</td>
<td>Wait</td>
<td>The car waited as I stood there.</td>
<td>Not motion verb</td>
</tr>
<tr>
<td>(+0)</td>
<td>Approach</td>
<td>I approached the stationary car</td>
<td>$A = \text{approach}$</td>
</tr>
<tr>
<td>(-0)</td>
<td>Reverse</td>
<td>I reversed my car behind the parked car</td>
<td>$A = \neg \text{approach}$</td>
</tr>
<tr>
<td>(+++)</td>
<td>Collide</td>
<td>I collided with an approaching</td>
<td>Not motion verb</td>
</tr>
<tr>
<td>(+-)</td>
<td>Followed</td>
<td>I was followed by the cops</td>
<td>Not motion verb</td>
</tr>
<tr>
<td>(--)</td>
<td>Split</td>
<td>I split ways at the crossing.</td>
<td>$A = \text{turn}$</td>
</tr>
<tr>
<td>(-0)</td>
<td>Move away</td>
<td>The Car moves away from me</td>
<td>$A = \text{leave}$</td>
</tr>
<tr>
<td>(++)</td>
<td>Follow</td>
<td>I followed the car in front</td>
<td>$A = \text{go}$</td>
</tr>
<tr>
<td>(0+)</td>
<td>Be passed</td>
<td>I was passed by the car</td>
<td>$A = \text{cross}$</td>
</tr>
</tbody>
</table>

Table 2: Links of Spatial actions and QTCN

The main aspect of this representation is that it assumes valid transactions between the QSR relations between objects and hence serves as a mechanism of classifying the actions into categories that enforce the validity. The relations correspond to the states that we have discussed in section 2.3.

Since spatial verb complex do not necessarily communicate about the states it is possible to state such restrictions only on verbs which clearly imply states at the start and/or end. In other case it may have to be implied or supplied complementarily. This leads to an assumption that we can only state our motion concepts in certain categories. Also these categories have to comply to spatio-temporal continuity constraints [Bennett et al 2004].

4 Summary and future work

We have presented a survey of principles in linguistic theories about motion related verbs and verb complexes. We have also stated the components of semantics associated to

2 The QTCN representation here represents the speaker and the observed object on the road as the objects in relative motion.
motion representations and intuition constraints. We discuss QSR approach to representation of motion and its link to linguistic notions.

This is only the preliminary work for a future investigation about deriving axiomatic specification of the components and constraints based on logical foundations like QSR. We suggest investigating the spatio-temporal continuity constraints of QSR in languages.

It is also required to examine causal structures [Croft, 2004] in motion verbs which can provide further theories about causes of spatio-temporal change which could constitute a higher level of logical reasoning (in the same way as reasoning about spatio-temporal change is a higher level of reasoning than the existence of spatial relations between objects)

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References
