Event shape: Paths in the semantics of verbs[1]

Joost Zwarts

Radboud University Nijmegen & Utrecht University

2006

1 Events as individuals

Much work on verbal semantics in the past twenty years or so has been shaped by Davidson's idea to treat events as individuals, as values of variables in first-order logic (Davidson 1967). A fairly standard analysis of sentence (1a) would be (1b):[2]

(1) a. Jack kissed Jill

 b. $\exists e$ [kiss(e) & Agent(e) = jack & Theme(e) = jill]

The verb *kiss* is interpreted as a one-place predicate over events, that is, as the set of kissing events. Thematic roles are functions that map events to participants, to the kisser and 'kissee' in this case (e.g. Parsons 1990). Interpreting verbs in this way has a range of well-known advantages. As Davidson (1967) already showed, it allows for an insightful analysis of verb modifiers as predicates over events. It has also helped our understanding of nominalizations, perception reports (Higginbotham 1983), thematic roles (Parsons 1990) and aspect (Bach 1986), among other things.

However, it is important to realize what a Davidsonian event semantics does and does not give us. Treating events as individual variables allows for events to be quantified over, to be referred to and to function as arguments. In other words, it tells us in what respect events are similar to individual 'things' (values of the variable *x*, so to say). But all by itself, it does not tell us much more about events and verbs or about how they differ from things and nouns. We are still left with the question what is 'inside' or 'behind' the *e*'s. Without a clear idea of properties that are characteristic of events, Davidsonian events won't help us much in explaining how verbs differ from one another. Probably the most influential approach to this

[2] The term *event* and the variable *e* is used here in the wide sense of *eventuality* (Bach 1986), encompassing not only achievements and accomplishments (events in the strict sense), but also states and processes.

issue is to assume that events have subevents and that verbs structure events in a particular way (e.g. Bach 1986, Pustejovsky 1991, Krifka 1998, Higginbotham 2000, Rothstein 2003 and many others). In the work of Bach and Krifka, event structure is an algebraic property of event *sets* (like cumulativity). Pustejovsky and Higginbotham decompose *individual* events into trees or pairs of processes and culminating states with more basic properties. For instance, an event of building a house is a transition e_0 consisting of a process e_1 (the activity of building) followed by a result state e_2 (the house being built). Whether the approach is algebraic or 'geometrical', the important thing is that the internal structure of events makes it possible to distinguish classes of verbs and apply event semantics in the study of verbal aspect and argument structure, thereby overcoming the limitations of simple Davidsonian e's.

Although I don't want to argue with the idea that events have subevents and internal structure, I do think that this approach risks putting the emphasis in the wrong place by treating event structure as the fundamental organizational principle of verb meanings. A similar point was made by Verkuyl (1993). I want to claim that event structure follows from a more basic and more general property of events: *event shape*. The shape of an event is the trajectory or contour that is associated to that event in space or in a scalar or conceptual domain. As I will show, focusing on motion verbs, this representation of event shape allows for a more unified treatment of a broader set of phenomena.

The rest of this paper is structured as follows. I will discuss five features of motion verbs in section 2, demonstrating the limitations of the event structure appoach. In order to overcome these limitations, I propose in section 3 to represent event shape by mapping events to spatial *paths* and show that the generalizations that we want to capture can be made at that level. Section 4 then explores an extension of this idea from motion verbs to scalar verbs and section 5 concludes with some prospects for further work.

2   Motion e's

How far can events and event structure get us in accounting for the properties of motion verbs? I want to discuss this question for five empirical domains. The intention is not to offer surprising data, but to draw attention to a couple of well-known, run-of-the-mill semantic facts that a general semantic theory of verbal meanings has to deal with. These facts concern such diverse properties as cross-categoriality, modification, opposition, aspect and 'fictive motion'. Internal subevent structure in motion events might go some way towards understanding these properties, but not far enough, as we will see.

2.1 Cross-categoriality

A semantic property is cross-categorial if it is not restricted to one particular part of speech, but applies across different syntactic categories. Motion verbs clearly share spatial properties with prepositions and adverbs. (2a) is more or less equivalent to (2b), because the meaning of *into* is in a sense semantically incorporated in the meaning of *enter* (Jackendoff 1983):

(2)   a.   The bear entered the cave
      b.   The bear went into the cave

In the same way the verb *approach* shares the meaning of 'increasing spatial proximity' with the adverb *nearer*, *rise* has something in common with the adverb *up* and *go around* can mean roughly the same thing as *to circle*.

How can we account for this cross-categoriality in a Davidsonian event analysis? Strictly speaking, a verb like *enter* is interpreted as a set of events, and such a set, all by itself, does not carry any information about the spatial properties of the events. One option would be to assume that events have structure (along the lines of Pustejovsky 1991, for instance). We might say that an event of entering the cave is really a pair $\langle e, e' \rangle$ of two more basic events, where e' is the culmination of the total entering event, the state of being *in* the cave and e is the process of motion that leads up to it (a 'telic pair' in Higginbotham 2000). The PP *into the cave* is similar, in that it licenses a bipartite event structures that culminates in a state of being in the cave. The difference between (2a) and (2b) is where the event splitting is expressed: in the verb or in the preposition.

It is not clear, however, how this extends to the next two cases mentioned above, where a culmination may be lacking. After all, *rise* and *go up* may be used atelically, to refer to processes:

(3)   a.   The balloon rose (for hours)
      b.   The balloon went up (for hours)

The same is true for *approach* and *nearer*. We could assume then that such motion processes are not *pairs*, but *sequences* of states $e_1 \ldots e_n$ over which a certain progression is specified. Every state e_i in the progression is a state of being closer to a landmark object (for *approach*

and *nearer*) or higher (for *rise* and *up*) than the state before, or, to choose a weaker formulation: the final state e_n is a state of being higher/closer to the landmark than the initial state e_1. This is again the kind of spatial information that can be expressed either in a verb or in an adverb or preposition, but it clearly does not have the same attractive simplicity as the binary event structure of *enter - into*.

But with the verb *to circle* and the adverb *around* it is simply impossible to account for cross-categoriality by decomposing events in terms of locative states. There is an overall shape to events of circling/going around that cannot be reduced to positions that are occupied at subevents. It is not possible to say what *to circle* and *to go round around* have in common without using the spatial notion of a trajectory in space, which is a property that goes beyond event structure. Both verbs and adverbs are used to describe properties of this trajectory.

We could of course still analyze the common spatial property of *to enter* and *into* in terms of event structure, while at the same time using trajectories to capture the similarity between *to circle* and *around*, but there is no a priori semantic reason to make such a distinction. The more general and natural solution is to analyze the spatial cross-categoriality of both *enter - into* and *circle - around* in the same way: by allowing spatial trajectories to play a role in the lexical semantics of different parts of speech.

2.2 Modification

Modification has often been used as a probe into the semantics of a word. One of the main arguments of Davidson for events in the representation of verbs came from modification (Davidson 1967):

(4)   a.   Jones buttered the toast with a knife in the bathroom at midnight

        b.   Jones buttered the toast

        a'. $\exists e$ [butter(e) & Agent(e)=jones & Theme(e)=the-toast & with-a-knife(e) & in-the-bathroom(e) & at-midnight(e)]

        b'. $\exists e$ [butter(e) & Agent(e)=jones & Theme(e)=the-toast]

Events accounts for the fact that adverbial modifiers are semantically optional, i.e. that (4a) entails (4b), because (4a') logically follows from (4b'). But adverbial modification also shows the restrictions of event semantics. Suppose we want to analyze the following three cases of modification in terms of events:

4

(5)   a.   Jill swam *across the lake*

    b.   The balloon rose *1800 m*

    c.   Jack approached *too closely*

Following the modification analysis of event semantics, we have to say that the italicized phrases are predicates of the event argument of the verb:

(6)   a. $\exists e$ [swim(e) & Theme(e)=jill & across-the-lake(e)]

    b. $\exists e$ [rise(e) & Theme(e)=the-balloon & 1800-m(e)]

    c. $\exists e$ [approach(e) & Theme(e)=jack & too-closely(e)]

Directly applying the modifiers to the event helps to account for the main fact that Davidson wanted to account for, namely that the modified sentence implies the non-modified sentence, but at the same time it leaves something important to be desired. What does it mean to say that an event is across the lake, or that it is 1800 m or too close? The event of swimming in (5a)is not located across the lake, it is somehow stretching across the lake. In the same way in (5b), the event of rising occurs over a trajectory that has a length of 1800m. The adverb *too closely* in (5c) does not say that Jack's approaching took place at a location that was too close; it's only the endpoint of his motion that is too close.

We want to know what kind of contribution PPs, measure phrases and adverbs make to motion verbs, but events or event structure do not give a general solution. The directional modifiers do not directly specify a property of the event (or a subevent), they specify a property of the spatial trajectory of the event and this trajectory does not reduce to an event structure property in a natural way.

2.3   Opposition

Verbs can be each other's opposites in different ways (Cruse 1986). Motion verbs can typically be opposite in *direction*, as in the following pairs:

(7)   rise - fall, enter - leave, ascend - descend, advance - retreat

These oppositions exist in virtue of the various spatial directions that these verbs express. There are also motion verbs that are their own opposite, like *circle*, *cross*, *jump*, *pass* and *zigzag*. These verbs are symmetric in a directional sense, because they lack the directedness that characterizes the verbs in (7).

The question now is how to capture this verbal opposition and symmetry in an event-based semantics.[3] Could there be an operation ~ of reversal in the domain of events, so that we can take an event e of rising, apply ~ and get an event of falling. Such an operation would allow us to say that *fall* is the reversal of *rise* and that *zigzag* is closed under reversals. One way to do this, is to decompose a motion event as a sequence of events $e_1 \ldots e_n$ with ~ as literally reversing this sequence to $e_n \ldots e_1$. What this solution fails to capture, however, is that the opposites in (7) are *directional* opposites, participating in a wider pattern of *spatial* opposites:

(8)   rise - fall, ascend - descend, up - down, above - below
       enter - leave, into - out of, inside - outside
       advance - retreat, forward - backward, front - back

Again, we see that motion verbs show the need to go beyond events, to the spatial trajectories that define the shape and directionality of those events.

2.4   Aspect

Motion verbs have lexical aspect or Aktionsart (see Hay, Kennedy and Levin 1999 and Rothstein 2003, 2004 for recent discussion). Some motion verbs are atelic, like *walk*, *swim*, *follow*, *zigzag*, others are telic, like *reach*, *arrive*, *leave*, *cross*. There are also two types of motion verbs that can go either way. A directed motion verb like *rise* can be either atelic or telic:

(9)   a.   The balloon rose (for hours)
       b.   The submarine rose (*for hours)

Depending on whether an implicit upper level is assumed or not, the verb is interpreted atelically (9a) or telically (9b) (where the upper level is the surface level of the sea). Another

---

[3] Pustejovsky (2000) discusses a somewhat different aspect of the relation between event structure and opposition.

telic/atelic ambiguity is found with a verb like *jump*, which can have a telic semelfactive reading ('jump once'), or an atelic iterative reading ('jump repeatedly').

(10) a.   Alex jumped (*for hours)

b.   Alex jumped (for hours)

It is possible to mirror the aspectual classification of verbs in the event structure, either by assigning internal structure to individual events or by mereologically structuring event denotations. It is important to realize, though, that aspectual class or event structure is not something separate from the lexical meaning of the verb, but it should follow from it. In other words, we want to explain why motion verbs like *zigzag*, *reach*, *rise* and *jump* have the aspectual properties that they have. The examples given here clearly suggest that it is the kind of spatial trajectory described by a verb that determines its event structure.

2.5 Fictive motion

As Jackendoff (1983), Talmy (1996), Gawron (2005) and others have discussed, some verbs, including motion verbs, show an ambiguity between a motion sense and an extension sense ('fictive motion' in Talmy's terms):

(11) a.   The missile zigzagged to the village

b.   The road zigzagged to the village

In both sentences, the verb *zigzagged* is modified by a directional PP. This modification presents a puzzle for an approach that captures the contribution of the directional PP in terms of event structure. An event can be structured into subevents that are temporally ordered with respect to each other, as we saw before. In the spirit of Higginbotham (2000) and Folli and Ramchand (2005), we could analyze the contribution of the PP *to the village* in (11a) as an ordered pair of events: the process of zigzagging and then the result state of being at the village. But it makes no sense to apply this analysis to (11b), because there simply is no temporal ordering of two events here, a process and a culmination and, moreover, (11b) is not even telic in the same way as (11a): it is *atelic* along the time dimension.

The approach of Jackendoff (1983) and Gawron (2005) capitalizes on the role of paths. What the events in (11a) and (11b) have in common, is a particular spatial trajectory, a path that goes to the village, but what differs is how this path is used in relation to the subject: as a

path of motion or as a path of extension. So, fictive motion is another area where reference to paths is essential for overcoming the limitations of event reference.

3   Spatial paths for motion events

The general idea of this paper is that motion events have a shape that is represented by means of a path in space. Cross-categorial properties pertain to paths, modifiers can specify properties of paths, and directional opposition is a relation between paths of events. Verbal aspect is determined by the algebra of paths associated to events and because paths are spatial, and not temporal entities, we can account for motion/extension alternations. In order to show how this works, we first need to say something more about paths.

3.0   Paths

The notion of path is commonly used in different semantic frameworks to analyze the meaning of expressions that describe how something is moving or extending in space.[4] It is an atemporal representation of a trajectory, a linear directed stretch of space. Because of its direction, positions along the path are ordered and there is a starting point and an end point. There are different ways to formalize the notion of path and most of them will allow us to represent event shapes. I will use the model that I worked out in Zwarts (2006), where a path is a continuous function from a real interval [0,1] to spatial points (given a particular model of points or regions). Let's call the number of [0,1] the indices of the path. If $\mathbf{p}$ is such a function, then $\mathbf{p}(0)$ is the starting point of the path, $\mathbf{p}(1)$ is its end point, and for every index i between 0 and 1, $\mathbf{p}(i)$ is an intermediate point. In this way a path corresponds roughly to a sequence of positions. Notice that the definition allows paths to cross themselves and to back up and cover the same stretch of space again in opposite direction.

We can define over the set of paths a subpath relation $\leq$, a partial operation + that maps paths $\mathbf{p}$ and $\mathbf{q}$ to their concatenation $\mathbf{p}+\mathbf{q}$, and an operation $\sim$ that gives the reversal $\sim\mathbf{p}$ of any path $\mathbf{p}$. A situation where $\mathbf{p} \leq \mathbf{q}$ is illustrated in Figure 1, concatenation of $\mathbf{p}$ and $\mathbf{q}$ in Figure 2, and the paths in Figure 3 are the reversals of those in Figure 1.

---

[4] Jackendoff (1983) contains a well-known exposition of path concepts that ties together earlier localist work. It also plays a role in Cognitive Grammar (e.g. Talmy 1983 and Langacker 1987) and in formal treatments (Habel 1989, Piñon 1993, Nam 1995, Krifka 1998 and Kracht 2002).
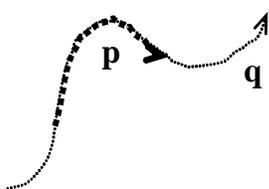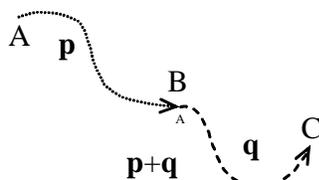
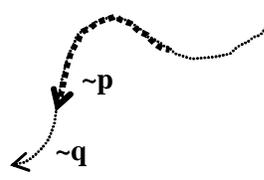Figure 1: Subpaths   Figure 2: Concatenation   Figure 3: Reversal

For further details about this algebra of paths, see Zwarts (2006).

The important thing now is how paths relate to events. This is where a function comes in that I call SHAPE and that maps events to their trajectory or contour, represented through a path.[5] It is a partial function that assigns unique paths only to those events that involve motion or extension in physical space. If e is the event of a bear entering a cave, then SHAPE(e) is the trajectory of the bear through space in that event. The theme of the event occupies subsequent positions of the path at subsequent stages of the event. We can see the SHAPE function as a thematic role, analogous in some respects to the agent and theme roles. It is a more restricted version of the kind of functions that other authors have introduced to map event structures into temporal and spatial structures (Link 1998 and Krifka 1998). It is also the major ingredient of the functions that Jackendoff uses in his Conceptual Structures to relate PATH concepts to EVENT concepts, like his GO function (Jackendoff 1983, 1996).

3.1 Cross-categorial paths

With this background, let us now take a look at the analysis of cross-categoriality. I will treat every directional PP or adverb as simply a set or predicate of paths, as first suggested by Piñon (1993) and further motivated in Zwarts (2006). The four words that we mentioned in section 2.1 can be defined as follows:

(12) a.   [[into NP]] = { $\mathbf{p}$: $\mathbf{p}(1)$ is inside [[NP]] }

      b.   [[nearer (to NP)]] = { $\mathbf{p}$: $\mathbf{p}(1)$ is closer to [[NP]] than $\mathbf{p}(0)$ }

      c.   [[up]] = { $\mathbf{p}$: $\mathbf{p}(1)$ is higher than $\mathbf{p}(0)$ }

      d.   [[around (NP)]] = { $\mathbf{p}$: $\mathbf{p}$ encloses [[NP]] }

The details of these informal definitions are not essential. Notions like 'inside', 'closer', 'higher than', 'encloses' can be made precise in various ways (using a vector-based model,

---

[5] In Zwarts (2006) this function is called TRACE. Nothing hinges on this change of terminology.

for instance, Zwarts and Winter 2000, Zwarts 2003). What is important is that we can define the denotations of these expressions as sets of paths by imposing conditions on the position or shape of the path. This is illustrated in the following figures.
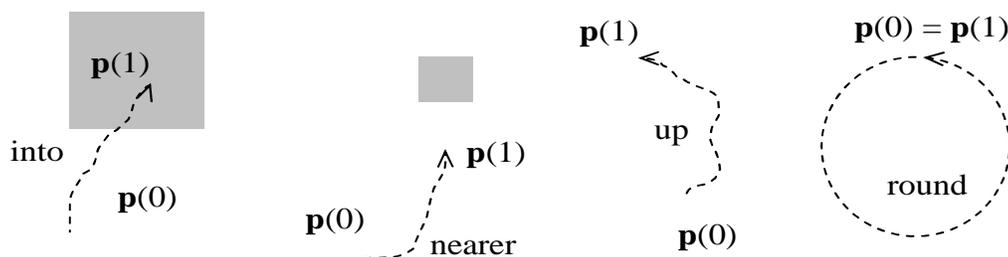

Figure 4: Paths corresponding to various prepositions and adverbs

The denotation of an *into* PP is a set of paths that ends in the reference object, as shown in Figure 4. *Nearer* holds for paths of which the end point is closer to the reference object than the starting point. *Up* denotes the set of paths that have a higher end point than starting point. *Around* is the most complex of all and one simple definition is difficult to give. For our purposes it is sufficient to say that *around* refers to paths that enclose the reference object, but Zwarts (2003) shows that *around* has a structure of meanings that all can be derived from a circular prototype. Other choices can be made for all of these four words, as variations within the idea that directional PPs and adverbs denote sets of paths.

From the definitions in (12) it is a small step to the definitions of the corresponding motion verbs, or rather, verb phrases. Assuming that each VP denotes a set of events, we can define these events directly in terms of underlying paths, through the SHAPE function:[6]

(13) a. ⟦ enter NP ⟧ = { e: SHAPE(e)(1) is inside ⟦ NP⟧ }

b. ⟦ approach NP ⟧ = { e: SHAPE(e)(1) is closer to ⟦ NP⟧ than SHAPE(e)(0) }

c. ⟦ rise ⟧ = { e: SHAPE(e)(1) is higher than SHAPE(e)(0) }

d. ⟦ circle (NP) ⟧ = { e: SHAPE(e) encloses ⟦ NP⟧ }

---

[6] It is necessary to include the direct objects of transitive motion verbs like *enter*, *approach* and *circle* in their definitions, because they are essential in providing the reference object of the paths. Strictly speaking, these transitive verbs are relations between objects and events, just like the corresponding prepositions are relations between objects and paths.

For example, *enter* corresponds to the set of events that are mapped to paths that have their end point inside the reference object. In the definitions, SHAPE first applies to the event, yielding a path **p** that can be applied to an index in the interval [0,1] to give a location that can be related to another location or to an object. In this way, the common spatial part of motion verbs and prepositions is made maximally explicit.

3.2 Modified paths

We can use the same approach for modification, by treating all directional verb modifiers as sets of paths. Assume that the modifiers from section 2.2 are defined as follows:

(14) a.   ⟦ across the lake ⟧ = { **p**: **p** is orthogonal to the length of the lake }

 b.   ⟦ 1800 m ⟧ = { **p**: **p** has a length of 1800 m }

 c.   ⟦ too closely ⟧ = { **p**: **p**(1) is too close to the implicit reference point }

Paths can have an orientation with respect to axes or sides of objects (*across*), they can have a length (*1800 m*) and they can have a position with respect to a reference object (*too closely* and *into* in the previous section). They can also have a direction (like *up*) or a shape (*around*). All of these properties can be specified through modifiers of the verb.

The interpretation of a modification structure is relatively simple:

(15) ⟦ V PP ⟧ = { $e \in$ ⟦ V ⟧: SHAPE(e) $\in$ ⟦ PP ⟧ }

The effect of adding the PP is restricting the set of events denoted by the verb to exactly those events that have a shape that can be found in the set of paths denoted by the PP. We can see how this works in the following examples:

(16) a.   swim *across the lake*

 { $e \in$ ⟦ swim ⟧: SHAPE(e) $\in$ ⟦ across the lake ⟧ }

 b.   rise *1800 m*

 { $e \in$ ⟦ rise ⟧: SHAPE(e) $\in$ ⟦ 1800-m ⟧ }

 c.   approached *too closely*

 { $e \in$ ⟦ approach ⟧: SHAPE(e) $\in$ ⟦ too closely ⟧ }

Given the characterization of *across the lake* in (14a), the example *swim across the lake* in (16a) boils down to the following:

(17) { *e*: e is a swimming event and SHAPE(*e*) is orthogonal to the length of the lake }

In this way the contribution of the modifiers can be accounted for in a compositional way. The directional modifiers do not apply directly to the events, as they did in a simple Davidsonian approach, but they apply to a specific property of the events, namely their shape.

3.3   Opposite paths

In section 3.0 we introduced an operation ~ that reverses paths. It allows us to show that paths denoted by *up* and *down* are each other's reversals and that *around* paths are their own reversals:

(18) a.   ⟦ up ⟧ = {~**p**: **p** ∈ ⟦ down ⟧ } and ⟦ down ⟧ = {~**p**: **p** ∈ ⟦ up ⟧ }

  b.   ⟦ around ⟧ = {~**p**: **p** ∈ ⟦ around ⟧ }

But using SHAPE, we can do the same for motion verbs:

(19) a.   { SHAPE(*e*): *e* ∈ ⟦ rise ⟧ } = { ~SHAPE(*e*): *e* ∈ ⟦ fall ⟧ } and vice versa

  b.   { SHAPE(*e*): *e* ∈ ⟦ circle ⟧ } = { ~SHAPE(*e*): *e* ∈ ⟦ circle ⟧ }

Rise and *fall* are each other's opposites in virtue of the reversal of their shapes and *circle* is its own reversal in this respect. Similar definitions to (19a) can be given for *enter – leave*, *ascend – descend*, *advance – retreat*, while symmetric verbs like *cross*, *jump* and *pass* are treated as in (19b).

3.4   Aspectual paths

We concluded in section 2.4 that the verbal aspect of motion verbs must depend in a crucial way on properties of the spatial trajectory that is part of their lexical meaning, i.e. their shape. How does event shape determine event structure and aspect?

The first step in answering this question requires a general way of making the distinction between telic and atelic events. In the spirit of the mereological and algebraic

12

approaches to nominal reference and verbal aspect in Bach (1986), Chierchia (1998), Krifka (1998), Link (1998), Rothstein (2003), I call a predicate P *unbounded* when it is cumulative, i.e. closed under sums. This means that when two entities *x* and *y* are P, then their sum is also P. A predicate is bounded when it is not closed under sums. Mass nouns and plurals (*water*, *furniture*, *bottles*) are unbounded under this definition, singular count nouns (like *bottle*, *drop of water*, *piece of furniture*) are bounded. The same definition makes state verbs and process verbs (*resemble*, *push*, *walk*) unbounded, and achievements and accomplishments (*walk a mile*, *arrive*) bounded. So, telicity is the verbal instantiation of boundedness.

In Zwarts (2006) I extend this notion of boundedness to the domain of directional prepositions and adverbs, using the operation of concatenation of paths introduced in section 3.0 as the sum operation. This gives us directional expressions that are either bounded or unbounded and this distinction follows directly from the way the path denotation of these expressions is defined. The following sets of paths are closed under concatenation:

(20) a. ⟦ towards the station ⟧ = { $\mathbf{p}$: $\mathbf{p}(1)$ is closer to the station than $\mathbf{p}(0)$ }

b. ⟦ along the river ⟧ = { $\mathbf{p}$: for every i $\mathbf{p}(i)$ is beside the river }

c. ⟦ up the hill ⟧ = { $\mathbf{p}$: $\mathbf{p}(1)$ is higher on the hill than $\mathbf{p}(0)$ }

For example, if two paths are along the river, then their concatenation is also along the river, because the property of having all points beside the river is preserved under concatenation. Other directional PPs or adverbs do not have this property of closure under concatenation and are therefore bounded:

(21) a. ⟦ over the line ⟧ = { $\mathbf{p}$: there is only one i such that $\mathbf{p}(i)$ is on the line }

b. ⟦ away ⟧ = { $\mathbf{p}$: $\mathbf{p}(1)$ is not near the reference point }

c. ⟦ up the hill ⟧ = { $\mathbf{p}$: $\mathbf{p}(1)$ is the highest position on the hill }

The PP *over the line* is not closed under concatenation because a concatention of two paths that go over the line yields a path that goes over the line *twice* (i.e. there are two points of the path that are on the line). See Zwarts (2006) for further discussion.

Notice that some expressions can go either way, depending on the definition that they get. *Up the hill* is unbounded on its 'comparative' sense ('higher and higher on the hill') and bounded on its 'superlative' sense ('to the highest point of the hill'). The adverb *around* is

ambiguous between a bounded 'singular' meaning and an unbounded 'plural' meaning ('around and around'):

(22) a.   ⟦ around ⟧ = { **p**: **p** is one complete circular path }
      b.   ⟦ around ⟧ = { **p**: **p** is a concatenation of complete circular paths }

With this general aspectual distinction, we can take the second step. It is well known that directional modifiers affect the telicity of the verb that they modify (Verkuyl & Zwarts 1992, Piñon 1993, Jackendoff 1996, Krifka 1998, Nam 2000, Zwarts 2006). The verb *walk*, for example, which is all by itself unbounded, leads to different kinds of aspect, depending on the modifier that it combines with. With the unbounded directionals *towards the station* and *along the river* the result is again unbounded, but the bounded directionals *over the line* and *away* make it bounded:

(23) a.   walk towards the station/along the river (for hours/*in an hour)
      b.   walk over the line/away (*for an hour)

The modifiers *up the hill* and *around* are compatible with both a bounded and an unbounded interpretation.

How does the modifier determine the aspect of the VP? One widely accepted line of explanation for aspectual composition makes use of a mapping (a homomorphism) that transfers the algebraic properties of the nominal domain to the verbal domain (Jackendoff 1996, Krifka 1998 and also Verkuyl 1993 in a different formulation), typically through the thematic roles that relate events and objects. In the same way, we can assume that SHAPE, the mapping between events and paths, transfers the properties of paths to events. If a directional modifier has cumulative (path) reference (i.e. is closed under sums), then the resulting modified VP has cumulative (event) reference and if it has non-cumulative reference, then so has the VP.

This works for structural cases of aspect composition, but I propose to use this also *internally* to the verb semantics, to account for how aspectual event structure is determined by the underlying spatial paths. There are motion verbs, like *walk*, *swim*, or *follow*, that can or must correspond to a path of motion, but that don't impose any conditions on the shape, length or direction of the path. As a result, the underlying set of paths is cumulative and the corresponding set of events is also cumulative. Hence, these verbs are atelic. Then there are

verbs like *zigzag* that impose very specific conditions on the geometry of the path of motion, but that still don't lead to non-cumulative reference. A concatenation of two zigzagging paths is again a zigzagging path, and so the verb *zigzag* is atelic.

Verbs like *enter*, *reach*, *leave* and *arrive* do impose conditions on their paths, more specifically on the starting points or end points of the paths:

(24) a. $[\![$ reach NP $]\!]$ = { e: only SHAPE(e)(1) is at $[\![$ NP$]\!]$ }

b. $[\![$ enter NP $]\!]$ = { e: only SHAPE(e)(1) is in $[\![$ NP$]\!]$ }

c. $[\![$ leave NP $]\!]$ = { e: only SHAPE(e)(0) is in $[\![$ NP$]\!]$ }

d. $[\![$ arrive PP $]\!]$ = { e: only SHAPE(e)(1) is $[\![$ PP$]\!]$ }

The underlying set of paths in each case is bounded and so is the resulting set of events. Notice that *arrive* is slightly different from the other verbs, by allowing the location for the end point of the path to be specified by a PP.

There are also ambiguous cases. The comparative/superlative alternation of *up* has its verbal counterpart with the verb *rise*. There is a comparative interpretation of *rise* ('higher and higher') and a superlative interpretation ('to the highest point'):

(25) a. $[\![$ rise $]\!]$ = { e: SHAPE(e)(1) is higher than SHAPE(e)(0) }

b. $[\![$ rise $]\!]$ = { e: only SHAPE(e)(1) is at the highest level }

An alternation of a different kind is found with the verb *jump*. This verb is complex and polysemous, but one prominent meaning involves a path that starts at the ground and ends at the ground with a middle part in the air:

(26) $[\![$ jump $]\!]$ = { e: only SHAPE(e)(0) and SHAPE(e)(1) are on the ground }

The resulting set of jumping events is bounded, representing the semelfactive interpretation of *jump*. One way to get the unbounded iterative meaning of *jump* is by forming concatenations of singular jumpings:

(27) $[\![$ jump $]\!]$ = { e: SHAPE(e) = $\mathbf{p}_1$+…+$\mathbf{p}_n$ and for every $\mathbf{p}_i$ only $\mathbf{p}_i$(0) and $\mathbf{p}_i$(1) are on the ground }

This instance of *jump* refers to a set that is unbounded. In all of these examples, the aspectual classes of the verbs don't need to be stipulated, but they follow from the lexical semantic conditions on the paths of motion on which they are based.

3.5 Extension paths

The final application of event shape is in the domain of extension readings for motion verbs. We have seen that the function SHAPE maps an event to a path, but we have not said anything about the role that this path plays in the semantics of the predication, taking into account the other participants in the clause and its temporal reference.

For motion, three dimensions of an event need to be coordinated: (i) the path assigned by SHAPE, (ii) the time interval of the event, TIME(e), and (iii) the THEME of the event, the entity that moves. Roughly speaking, THEME(e) is located at subsequent positions of SHAPE(e) at subsequent moments of TIME(e). To formalize this, I assume that the spatial path and the temporal interval of a motion event are related through a homomorphism (Jackendoff 1996):

(28) Event e is a motion event, MOTION(e), iff there is a monotone increasing homomorphism h from TIME(e) to [0,1] such that for every $t \in$ TIME(e), THEME(e) is located at SHAPE(e)(($h(t)$)).

One of the things that follows from this definition is that motion along a path entails location at positions of that path, which is why (29a) entails (29b):

(29) a. Alex went *through* the park
      b. Alex was *in* the park

In extension events there is no motion of the theme along the path of event, but a distribution of the theme along the path. This is a much more complicated situation, that requires a decomposition of the theme into parts with respect to its major dimension. Let's simply assume that there is a function SLICES that gives an ordered set of parts ('slices') of the theme:

(30) Event e is an extension event, EXTENSION(e), iff there is a monotone increasing homomorphism h from SLICES(THEME(e)) to [0,1] such that for every $x \in$ SLICES(THEME(e)), x is located at SHAPE(e)($h(x)$) at at any $t \in$ TIME(e).

In this case, the homomorphism does not go from time to path, but from 'matter' to path. There are other, more adequate, ways to do this with wider empirical coverage (as in Gawron 2005), but this formulation brings out the analogy between motion and extension in a simple and transparent way. We can define the event denotation of a VP like *zigzag to the village* in neutral terms, as a set of events with a particular shape (given by the verb) and direction (given by the PP):

(31) $[\![$ zigzag to the village $]\!]$ = { $e \in [\![$ zigzag $]\!]$: SHAPE(e) $\in [\![$ to the village $]\!]$ } =
      { e: SHAPE(e) is a zigzag & SHAPE(e)(1) is at the village }

In order to make clear whether we are dealing with motion or extension, we have to add this information separately:

(32) a.   The missile zigzagged to the village
            { e: MOTION(e) & THEME(e)=the-missile & e is a zigzagging to the village }
      b.   The road zigzagged to the village
            { e: EXTENSION(e) & THEME(e)=the-road & e is a zigzagging to the village }

Whether a sentence is interpreted as motion or extension depends on the kind of theme that are used (missile or road) and on the verb. Many verbs don't have the ambiguity of *zigzag*, but are more specialized in either a motion or extension use (see Jackendoff 1996, Talmy 1996, Gawron 2005).

All of the five properties of motion verbs that we discussed depend in a crucial way on event shape, on the association of spatial paths to verbs. Because of event shape, verbs can share spatial properties with prepositions and adverbs, they can be spatially modified, stand in opposition to other verbs, and exhibit both motion and extension readings. In the next section we will see that the notion of event shape can be taken much broader than the spatial domain.

4   Scalar event shapes

The claim that I would like to make is that besides motion verbs many other verbs also have an event shape, but that the trajectory described by the event is not spatial, but part of another domain. Here I will restrict myself to one non-spatial domain: that of scales and degrees. This application can be illustrated first of all for a class of verbs that are called degree achievements in the literature, verbs like *lengthen*, *shorten*, *widen*, *cool*, *straighten*, *broaden*, and *empty* (Hay, Kennedy and Levin 1999, Rothstein 2004). The events referred to by these verbs have shapes that can be formalized as paths in one-dimension scales, along the lines of section 3.0.

To make this concrete, assume that the scale of length is a half line, that represents the ordered set of lengths, from zero up. Adjectives like *long* and *short* and measure phrases like *approximately two meters* denote regions on this scale, but here we are interested in the role of changes in length in the interpretation of verbs like *lengthen* en *shorten*. For this we need paths that are very much like the spatial paths that we saw in section 3, only restricted to this special one-dimensional non-physical space. Intuitively, events of lengthening are associated to upward paths on the length scale and events of shortening to downward paths. This helps us to account for a range of phenomena, analogous to the situation with motion verbs.

We find cross-categoriality, this time between verbs and adjectives, like *lengthen* and *longer* or *grow* and *bigger*. Intransitive *lenghten*, for example, can be paraphrased as *become longer*.[7] We can account for this by treating comparative adjectives like *longer* semantically as paths on a scale, such that the end point of the path is higher ($>$) on the scale than the starting point and the same kind of paths that are assigned to events of lengthening:

(33) a. $[\![$ longer $]\!]$ = { $\mathbf{p}$: $\mathbf{p}(1) > \mathbf{p}(0)$ on the scale of length }

  b. $[\![$ lengthen $]\!]$ = { e: SHAPE(e)(1) $>$ SHAPE(e)(0) on the scale of length }

This makes *longer* a scalar and adjectival counterpart of the directional adverb *up*. The verb *lengthen* is like *rise*: it is associated to paths that go up on the length scale.

Modification possibilities with degree achievements are accounted for along the same lines. Take the verb *widen*, that allows measure phrases (*widen 2 meters*), but also PPs (*widen from 10 to 12 meters*).

---

[7] See also Zwarts, Hendriks and de Hoop (2005) for further discussion on the special status of such 'reflexive' comparatives.

(34) a.   ⟦ widen 2 meters ⟧ = { e: SHAPE(e) ∈ ⟦ 2 meters ⟧ }

      b.   ⟦ widen from 10 to 12 meters ⟧ = { e: SHAPE(e) ∈ ⟦ from 10 to 12 meters ⟧ }

In the first case the measure phrase simply specifies the length of the scalar path. The second case is more interesting, because it shows that the analogy between the spatial and scalar domain even includes prepositional phrases (as also noted in Krifka 1998). This shows that the scalar analysis that Hay, Kennedy and Levin (1999) give of degree achievements is too limited. In their account the modification and aspectual properties of degree achievements like *widen* are based on difference values on a scale. The measure phrase *2 meters* in (34a) specifies such a difference value. But the PP modifier in (34b) shows that we need more than 'difference values' or 'degrees of change' to capture the meaning of degree achievements; we also need starting points and end points of changes in width. More specifically: we need *paths* instead of *degrees*.

      Obviously, opposition of the kind *lengthen - shorten* can also be treated using event shapes. The shapes of these two verbs are each other's reverses:

(35)   { SHAPE(e): e ∈ ⟦ lengthen ⟧ } = { ~SHAPE(e): e ∈ ⟦ shorten ⟧ }

Every path that goes down on the scale (a shortening path) is the reversal of a path that goes up on the scale (a lengthening path). The events are each other's opposites only in virtue of the scalar trajectories.

      The underlying path is also important for explaining the aspect of degree achievements. As was pointed out in Hay, Kennedy and Levin (1999), deadjectival verbs are not all the same aspectually. Notice, for instance, the contrast between *straighten* and *lengthen*.

(36)   They are ?straightening/lengthening the rope for hours (aspect)

The underlying scale plays an important role here. Length is an open scale (a scale without an inherent maximum length), while straight, on the other hand, is a closed scale (a scale with a maximal straightness). This is why we can say *completely straight*, but not *completely long*. And this is also why the set of paths correponding to *lengthen* can be unbounded, as in (37a), but the set corresponding to *straighten* can only be bounded, because the underlying scalar paths end at the endpoint of the straight scale:

(37) a.   ⟦ lengthen ⟧ = { e: SHAPE(e)(1) > SHAPE(e)(0) on the scale of length }

      b.   ⟦ straighten ⟧ = { e: SHAPE(e)(1) is at the endpoint of the straight scale }

Finally, with degree achievements we also see an alternation between change and extension that is similar to the motion/extension alternation. Here are two examples from Gawron (2005):

(38) a.   The crack widened at the north gate

      b.   The crack widened from the tower to the north gate

The widening can either be a change over time at one particular spatial location or it can be a property of the crack as a whole that it is wider at the north gate than at an other location. The latter situation can be made more specific by spatially describing the path of this widening pattern: it starts at the tower and ends at the north gate. From the perspective of this paper, the common meaning of *widen* is a scalar path: a path that goes up on the width scale:

(39) ⟦ widen ⟧ = { e: SHAPE(e)(1) > SHAPE(e)(0) on the scale of width }

The dynamic interpretation of *widen* involves a homomorphism that embeds the path into time by mapping the temporal slices of the event to the indices of the path, in order to assign increasingly higher width degrees to one particular part of the crack. The stative interpretation of *widen* involves an embedding of the scalar path in the spatial extent of the crack: slices of the crack are mapped to the indices, with the result that increasingly higher width degrees are assigned to subsequent parts of the crack.

Conclusion

Paths play a crucial role in the semantics of verbs, not only of motion verbs, but also of degree verbs. I have tried to argue that paths are a more effective tool than event structure in the analysis of phenomena like cross-categoriality, modification, opposition, aspect and fictive motion. It is important to note that event structure might still play a role as a derivative of event shape, with implications for argument structure and syntactic structure (see Folli and Ramchand 2005, for one possible way of connecting event, argument and phrase structure).

This is one important area that falls outside the scope of this paper. As is well-known from the literature, the structure of events clearly interacts with thematic role assignment, with causality and agentivity, and it has implications for syntactic and cross-linguistic properties. However, I have abstracted away from such issues here, keeping the discussion of the wider implications of event shape for another occasion. Another important area that goes beyond the scope of this paper concerns the non-monotonic interaction between verb meaning and spatial modifiers and the role of manner of motion. See Weisgerber (2005) for a possible line of analysis in which paths play an important role.

The event shape approach laid out here can be construed as a kind of upside-down application of the role that paths play in Jackendoff's Conceptual Structure, where functions like GO and EXT map THINGs and PATHs to EVENT concepts. Just like in his system the verb *enter* is analyzed as involving the functions GO, TO and IN, we could imagine many more event concepts to incorporate paths, with a richer idea of paths. I'm not sure, however, to what extent that is compatible with the spirit of Jackendoff's conceptual structure, where PATH concepts are very close to the grammatical categories of prepositions and adverbs. Furthermore, the internal structure of PATH concepts is also very much tied to a small inventory of functions like TO and VIA (Jackendoff 1991). The approach sketched here requires a much broader notion of path, including zigzagging, circular and up and down paths and it is not clear to what extent such rich spatial notions belong in a conceptual representation (and not in a non-conceptual spatial representation). How event shape fits into a more general and cognitive oriented view on representations is something for another occasion.

This also relates to the issue of restrictiveness. A restrictive theory that makes very specific claims about event shape (like the event decomposition proposal of Pustejovsky 1991 and Higginbotham 2000) or path concepts (like the conceptual structure theory of Jackendoff) has clear a priori advantages over a theory that seems to allow any set of paths through some conceptual domain to determine a possible meaning for prepositions or verbs. The challenge for the approach of this paper is to formulate constraints on what constitutes a possible path-based meaning, not only for prepositions, but also for adverbs and verbs. These constraints might vary with conceptual domain or syntactic category and it would be interesting to define measures of path complexity that we can correlate with perceptual, conceptual or grammatical complexity.

The notion of event shape used here, resonates in an interesting way with event and aspect representations found in cognitive semantics (e.g. Talmy 1978, Croft to appear), where

dynamic verb meanings are analyzed into a closed variety of transitions between qualitative states, leading to different aspectual 'contours'. One area for future research is to extend the path notion used here to include all dynamic verbs, encompassing also events that describe trajectories in all sorts of conceptual or qualitative spaces. This is in the spirit of Gärdenfors' (2000) theory of Conceptual Spaces, that tries to build bridges between cognitive and formal approaches to lexical semantics. Making this work is not a trivial matter, as shown in Geuder and Weisgerber (2002, 2005). While the dimensions of spatial and scalar spaces are relatively simple and clearly defined, this is not always the case for other conceptual spaces. Nevertheless, despite (or, rather, thanks to) these challenges the event shape approach seems certainly worth trying.

References

Bach, Emmon (1986). The Algebra of Events. *Linguistics and Philosophy* 9, 5-16.

Chierchia, Gennaro (1998). Plurality of mass nouns and the notion of "semantic parameter". In Susan Rothstein, ed., Events and Grammar. Dordrecht: Kluwer, 53-103

Croft, William (to appear). Aspectual and causal structure in event representations. In V. Gathercole, ed., *Routes to Language Development: In Honor of Melissa Bowerman*. Mahwah:, New Jersey: Lawrence Erlbaum Associates.

Cruse, D.A. (1986). *Lexical Semantics*. Cambridge: Cambridge University Press.

Davidson, Donald (1967). The Logical Form of Action Sentences. In Nicholas Rescher ed., *The Logic of Decision and Action*, Pittsburgh: University of Pittsburgh Press, 81-95.

Folli, Raffaella and Gillian Ramchand (2005). Prepositions and results in Italian and English: An analysis from event decomposition. In Henk Verkuyl, Henriëtte de Swart and Angeliek van Hout, eds., *Perspectives on Aspect*. Springer.

Gawron, Jean Mark (2005). Generalized paths. Paper presented at SALT XV.

Geuder, Wilhelm and Matthias Weisgerber (2002). Verbs in Conceptual Space. In Graham Katz, Sabine Reinhard and Philip Reuter, eds., *Proceedings of SuB6*. University of Osnabrück, 81-83.

Geuder, Wilhelm and Matthias Weisgerber (2005). On the Geometrical Representation of Concepts. Ms. Universität Konstanz.

Habel, Christopher (1989). *Zwischen*-Bericht. In Christopher Habel, Michael Herweg and Klaus Rehkaemper, eds., *Raumkonzepte in Verstehensprozessen: Interdisziplinäre Beiträge zu Sprache und Raum*. Tübingen: Niemeyer, 37-69.

Hay, Jennifer, Christopher Kennedy and Beth Levin (1999). Scalar Structure Underlies Telicity in "Degree Achievements". In T. Mathews and D. Strolovitch, eds., *SALT IX*. Ithaca: CLC Publications, 127-144.

Higginbotham, James (1983). The Logic of Perceptual Reports: An Extensional Alternative to Situation Semantics. *Journal of Philosophy* 80, 100-27.

Higginbotham, James (2000). Accomplishments. *Proceedings of Glow in Asia II*, 72-82.

Jackendoff, Ray (1983). *Semantics and Cognition*. Cambridge, Massachusetts: MIT Press.

Jackendoff, Ray (1991). Parts and boundaries. *Cognition* 41, 9-45.

Jackendoff, Ray (1996). The proper treatment of measuring out, telicity, and perhaps even quantification in English. *Natural Language and Linguistic Theory* 14, 305-354.

Kracht, Marcus (2002). On the semantics of locatives. *Linguistics and Philosophy* 25, 157 - 232.

Krifka, Manfred (1998). The origins of telicity. In Susan Rothstein ed., *Events and Grammar*. Dordrecht: Kluwer, 197-235.

Langacker, Ronald W. (1987). *Foundations of Cognitive Grammar. Vol. 1: Theoretical Prerequisites*. Stanford: Stanford University Press.

Link, Godehard (1998). *Algebraic Semantics in Language and Philosophy*. Stanford, California: CSLI Publications.

Nam, Seungho (1995). The Semantics of Locative Prepositional Phrases in English. Ph.D. dissertation UCLA.

Nam, Seungho (2000). A typology of locatives and event composition in English. *Language Research* 36.4, 689-714.

Parsons, Terence (1990). *Events in the Semantics of English: A Study in Subatomic Semantics*. Cambridge, Massachusetts: MIT Press.

Piñon, Christopher J. (1993). Paths and their names. In Katherine Beals et al. eds., *Chicago Linguistics Society* 29, Volume 2. Chicago: Chicago Linguistics Society, 287-303.

Pustejovsky, James (1991). The syntax of event structure. *Cognition* 41, 47-81.

Pustejovsky, James (2000). Events and semantics of opposition. In Carol Tenny & James Pustejovsky, eds., *Events as Grammatical Objects*. Stanford, CA: CSLI Publications, 445-482.

Rothstein, Susan (2003). *Structuring Events: A study in the semantics of lexical aspect*. Oxford: Blackwell Publishing.

Rothstein, Susan (2004). Two puzzles for a theory of lexical aspect: semelfactives and degree achievements. Paper presented at the *Workshop on Event Structures in Linguistic Form and Interpretation*, Leipzig.

Talmy, L. (1978). The Relation of Grammar to Cognition - A Synopis. In D. Waltz, ed., *Theoretical Issues in Natural Language Processing 2*. New York: Association for Computing Machinery. 14-24.

Talmy, L. (1983). How language structures space. In H. Pick and L. Acredolo, eds., *Spatial orientation: Theory, research, and application*. New York: Plenum Press, 225-282.

Talmy, L. (1996). Fictive Motion in Language and "Ception". In Paul Bloom., Mary A. Peterson, Lynn Nadel, and Merrill F. Garrett eds., *Language and Space*. Cambridge, Massachusetts: MIT Press, 211-276.

Verkuyl, Henk (1993). *A Theory of Aspectuality: The Interaction between Temporal and Atemporal Structure*. Cambridge: Cambridge University Press.

Verkuyl, Henk and Joost Zwarts (1992). Time and space in conceptual and logical semantics: the notion of Path. *Linguistics* 30, 483-511.

Weisgerber, Matthias (2005). Where Lexical Semantics Meets Spatial Description: A Framework for Klettern and Steigen. In Emar Maier, Corien Bary and Janneke Huitink, eds., *Proceedings of SuB9*. Nijmegen: NCS, 507-521.

Zwarts, Joost (2003). Paths round a prototype. In Patrick Saint-Dizier, ed., *ACL-SIGSEM workshop: The Linguistic Dimensions of Prepositions and their Use in Computational Formalisms and Applications*. Toulouse: IRIT, 228-238.

Zwarts, Joost (2006). Prepositional aspect and the algebra of events. To appear in *Linguistics and Philosophy*.

Zwarts, Joost, Petra Hendriks and Helen de Hoop (2005). Comparative paths to an optimal interpretation. In E. Maier, C. Bary and J. Huitink, eds., *Proceedings of SuB9*. Nijmegen: NCS, 553-563.

Zwarts, Joost and Yoad Winter (2000). Vector space semantics: A model-theoretic analysis of locative prepositions. *Journal of Logic, Language and Information* 9.2, 171-213.