Enriching the Notion of Path in ISOspace

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Abstract

This paper proposes a modification to the notion of \textit{PATH} as used in ISOspace, in order to both simplify the semantics of the \textit{MOVELINK} tag as well as improve its coherence as a link structure, as defined in Bunt et al. (2016). This follows a suggestion by Lee (2016), where a reformulation of \textit{MOVELINK} is proposed, in effect restoring an earlier proposal by Pustejovsky et al. (2010), where a motion is a relation between a \textit{MOVER} and an \textit{EVENT_PATH}. This simplifies the specification in ISOspace, maintains a coherent abstract syntax, and avoids redundancy with the annotation of semantic role labels.

1 Elements of ISOspace

As part of an ISO international standard on semantic annotation, ISOspace (ISO-24617-7, 2014) provides an abstract syntax, represented in UML diagrams, two concrete syntaxes, and a set of guidelines for the annotation of spatial entities and motions in language. It specifies: (a) how to annotate spatial entities such as places, paths, and spatially involving non-locational objects and motions and other non-motion events in language; and (b) how to annotate and represent their relations in a concrete format, either XML or predicate-logic-like form. The specification for ISOspace distinguishes between four major types of spatially relevant elements for markup in natural language (Pustejovsky, 2017).

(1) a. \textbf{PLACES AND SPATIAL ENTITIES}: natural or artificial locations in the world, as well as objects participating in spatial relations.
    b. \textbf{EVENTS AND MOTION EVENTS}: Eventualities involving movement and static situations.
    c. \textbf{SPATIAL SIGNALS AND SPATIAL MEASURES}: linguistic markers that establish relations between places and spatial entities.
    d. \textbf{SPATIAL RELATIONSHIPS}: The specific qualitative configurational, orientational, and metric relations between objects.

In the discussion below, we focus on those elements of ISOspace that are most relevant for modeling motion events. We begin with the six basic entity types, given below.

(2) a. \textbf{PLACE} d. \textbf{MOTION events}
    b. \textbf{PATH} e. \textbf{EVENT} (non-motion)
    c. \textbf{SPATIAL ENTITY} (non-locational) f. \textbf{SIGNAL} (three types)

The \textbf{PLACE} tag is used for annotating geographic entities like lakes and mountains, as well as administrative entities like towns and counties. (3) shows extents that should be captured with \textbf{PLACE}.

(3) a. [\textbf{Boston}_p] is north of [\textbf{New York}_p].
    b. John entered the [\textbf{store}_p].
    c. Kiyong flew to [\textbf{Montpellier}_p].
With the exception of implicit, non-consuming tags, a PLACE tag in ISOspace must be directly linked to an explicit span of text.

The PATH tag is used to capture locations where the focus is on the potential for traversal or functions as a boundary. This includes common nouns as in (4a) and (4b) as well as proper names as in (4c). The attributes of the PATH tag are a subset of the attributes of the PLACE tag, but with the additional beginID, endID, and midIDs attributes.

(4) a. ... I arrived at the end of the [road_p1].
   b. ... a massive mountain [range_p2] that hugs the west [coast_p3] of Mexico.
   c. I followed the [Pacific Coast Highway_p4] along the coastal mountains ...

Finally, a SPATIAL_ENTITY is a named entity that is both located in space and participates in an ISOspace link tag. It is generally anything that is spatially relevant but does not fit into either the PLACE or PATH categories. In practice, moving objects and objects that have the potential to move are most commonly tagged as a SPATIAL_ENTITY. In both (5a) and (5b), car should be marked as a SPATIAL_ENTITY. In the first case, it is the mover and, in the second case, it behaves like a PLACE. Note, though, that it should still be annotated as a SPATIAL_ENTITY and not be annotated as a PLACE since cars still have the potential for movement.

(5) a. The [car_sne1] drove down the street.
   b. [John_sne1] arrived at the [car_sne2].
   c. My [father_sne1] and [I_sne2] biked for two days.

ISOspace has four types of relation tags, called links, holding between entity structures, illustrated below.

(6) a. QSLINK – qualitative spatial links;
   b. OLINK – orientation information;
   c. MOVELINK – movement links;
   d. MLINK – measuring dimensions of locations

A QSLINK captures the topological relationship between two spatial objects, and are usually triggered by topological SPATIAL_SIGNALS. Topological information primarily refers to containment and connection relations between a pair of locations. ISOspace uses the Region Connection Calculus (RCC) as the basis for its qualitative spatial relationships (Randell et al., 1992). RCC8 is concerned with how regions (spatial objects) are connected to each other. The combination of RCC8’s jointly exhaustive and pairwise disjoint relations, along with IN (the disjunction of TTP and NTTP) is referred to in ISOspace as RCC8+. Figure 1 visualizes the basic RCC8 relations.

Figure 1: Visual Correspondence of RCC8 Relations

Briefly, the OLINK tag covers those relationships that occur between two locations that are non-topological in nature. Orientation links essentially fill in information that QSLINKs fail to capture, including direction, orientation, and frame of reference. Finally, the MLINK tag serves two purposes in ISOspace: to capture the distance between two spatial objects; or to describe the dimensions of a single object. See Pustejovsky (2017) for details on both of these relation types.

Finally, we come to the MOVELINK. The MOVELINK tag is used to connect all of the elements that are involved in a motion event, including the MOTION event itself, the mover, the source, goal, midPoints, and ground of the MOTION, an explicit path, if there is one, (i.e., pathID) and any adjuncts that are present (i.e., adjunctID). The trigger of a MOVELINK is always a MOTION ID and the mover is normally a SPATIAL_NE. Table 1 shows the attributes for the MOVELINK tag.
| id | mv1l, mv12, mv13, … |
| trigger | identifier of the motion event that triggered the link |
| source | identifier of the place, path, spatial named entity, or event at the beginning of the path |
| goal | identifier of the place, path, spatial named entity, or event at the end of the path |
| midPoint | identifier of the place, path, spatial named entity, or event in the middle of the path |
| mover | identifier of the entity that moves along the path |
| ground | identifier of a place, path, spatial named entity or event that the mover’s motion is relative to |
| goalReached | TRUE, FALSE, UNCERTAIN |
| pathID | identifier of a path that is equivalent to the one described by the MOVELINK |
| adjunctID | identifier of the spatial signal that participates in the link |

Table 1: Attributes for MOVELINK

2 Problems with MOVELINK

It is perhaps important to understand that the motivation for the MOVELINK tag in ISOspace comes originally from an interest in tracking objects in motion, as described in texts, and then linking them to maps or other visual geographic displays (Pustejovsky and Moszkowicz, 2008). As such, this results in a conflation of two kinds of information structures: (i) a relation between a motion and the mover in the motion; and (ii) all of the semantic roles that are involved in a motion event. This has the unintended consequence of creating a link structure that overlaps with efforts to annotate semantic roles generally, i.e., SemAF-SR (24617-4, 2014), and specifically within spatial language (Kordjamshidi et al., 2012). Moreover, it is unlike the other relational structures in ISOspace, in that it identifies no actual relation type, independent of the motion event itself. In this sense, it fails to conform to the definition of a link structure, as proposed in Bunt et al. (2016). For these reasons, following Lee (2016), we propose to simplify the structure of the MOVELINK tag as a relation between a MOVER and the path created by the movement, namely the EVENT_PATH.

3 The Return of EVENT_PATH

In ISOspace version 1.3e, Pustejovsky et al. (2010) introduced an additional tag to the elements listed in Section 1 above, namely an EVENT_PATH. The original intuition behind this type was to have a record of the movement as carried out by the mover: that is, to encode the path created by the traversal of an entity in motion. In order to make this more transparent, following Mani and Pustejovsky (2012), Pustejovsky and Yocum (2013) introduce two axioms of motion into the abstract syntax of ISOspace, given below.

(7) a. Axiom 1: Mover Participants
Every motion-event involves a mover.
\[ \forall e \exists x [motion-event(e) \rightarrow mover(x, e)] \]

b. Axiom 2: Event Paths
Every motion-event involves an event-path.
\[ \forall e \exists p [motion-event(e) \rightarrow [event-path(p) \land loc(e, p)]] \]

These axioms presuppose the following definitions:

(8) MOVER: participant in a motion-event that undergoes a change in its location.
PATH: non-null sequence of locations (places).

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1See Pustejovsky and Yocum (2013).

2Langacker (2008) (p.356) introduces mover as one of the six archetypal roles associated with actions and events, while defining it as "anything that moves (i.e. changes position in relation to its external surroundings)". He also treats the mover as a trajector in contrast to a landmark that provides a ground for the activity or motion of a trajector. These two terms, trajector and landmark, correspond to the terms figure and ground in our use related to motion-events.
EVENT-PATH:

Formal: path which is directed, finite, and bounded with a begin-point, an endpoint, and a sequence of midpoints between them;

Functional: path triggered by a motion-event, that traces or represents the locational (physically necessary spatio-temporal) transition or trajectory of the mover, of a motion-event.

To illustrate the role of EVENT-PATH in the context of motion, let us consider some examples.

(9) a. John_mover walked from Boston to Cambridge.
   b. An arrow_mover hit the target.
   c. John pushed a big rock_mover over the hill.

As shown above, the mover is not necessarily an agent or the cause of a motion. Whatever their semantic roles, however, all these movers above have the characteristics of moving from one location to another. Hence, to understand what is meant by mover, some locational change of an object must be implied from a motion.

By the two definitions given above, the mover in Axiom 1 is understood to be locationally related to the event-path in Axiom 2. By Axiom 1, an object x is related to a motion-event e and then by Axiom 2 the motion-event e to an event-path p with the relation loc. Hence, the mover x is locationally related to the path p, provided that transitivity is assumed to hold. Following Pustejovsky and Moszkowicz (2011); Lee (2016), to make the relation between the mover and the path more explicit, we introduce the following additional axiom:

(10) Every motion-event has a path to which it is anchored, and the mover traverses that path.

\[ \forall e \exists \{p, x\} [\text{motion-event}(e) \rightarrow [\text{event-path}(p, e) \land \text{mover}(x, e) \land \text{traverse}(x, p)]] \]

We assume that traversal can be defined as follows:

(11) TRAVERSE:

a. A binary relation between an object x and a path p such that traverse(x, p) holds if and only if, for any path p, represented as \(<l_0, \ldots, l_k>\) with two endpoints \(l_0\) and \(l_k\), and any object x, each of the locations of x, represented as \(l(x)\), in its transition from one location to another, corresponds to each location \(l_i\) in p.

b. For an object x and a path p such that p is a sequence \(<l_0, \ldots, l_k>\), \(\sigma(\text{traverse}(x, p))\) implies:

\[ \forall t_i \in \mathbb{N} \left[ t_0 \leq t_k \rightarrow [\text{loc}(x, t_0), \ldots, \text{loc}(x, t_k)] \right] \]

4  Reformulation of MOVELINK

Given these observations, we propose that MOVELINK can be recast as a proper link structure, as a relation between a FIGURE and GROUND, to be defined below. A link structure, \(<\eta, E, \rho>\), within the abstract syntax \(\mathcal{ASyn}_{\text{isoSpace}}\) of ISOspace, has the following properties (Bunt et al., 2016).

(12) a. \(\eta\) is an entity structure of the spatial entity type functioning as the mover of a motion-event and as its figure,

b. \(E\) is a singleton containing an entity structure of the event-path type functioning as a ground;

c. \(\rho\) is a relation over \(\eta\) and \(E\) triggered by a motion-event.

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\(\text{event-path}\) is here treated as a relation between a path and an event because, unlike a (static) path, an event-path is created by a motion-event. \(\text{loc}(e, p)\) holds if and only if \(\text{traverse}(x, p)\) holds for each \(l\) in \(p\).
We assume the mover of a motion to be a *figure*, as suggested by Talmy (1975, 1985). For its interpretation then, each event-path or traversal of the mover of a motion-event requires a reference location, either a place or a path, called *ground*.

The movement link is triggered by a motion-event. In the modified version of ISOSpace, this link is viewed as relating the mover of that motion-event to an event-path traversed by the mover. The *MOVER* and *EVENT-PATH* are then treated as the *figure* and *ground* of the movement link, respectively. The revised structure for *MOVELINK* is shown below.

| id     | mvl1, mvl2, mvl3, … |
|--------|---------------------|
| trigger| identifier of the motion event that triggered the link |
| relType| relation value of motion, defaults to *traverse* |
| figure | identifier of the entity that moves along the path |
| ground | identifier of the event-path of the motion |

Table 2: Revised MOVELINK

To illustrate how this plays out, consider the different ways in which a mover can relate to the event-path, as it unfolds in a motion event. We demonstrate this with the distinction that Talmy and others have observed between *internal motion* and *external motion*: below, *se* is *SPATIAL_ENTITY*, *m* is *MOVE_EVENT*, and *ep* is *EVENT_PATH*.

(13) a. John swam around the lake.
   \[ \text{John}_{se1:figure} \text{swam}_{m1:trigger} \text{around}[ \text{the lake}_{ep1:ground} ] \]

   b. John walked around the lake.
   \[ \text{John}_{se1:figure} \text{walked}_{m1:trigger} [ \text{around the lake}_{ep1:ground} ] \]

In (13a), the motion that John is involved in is internal to the region identified as the *figure*, hence the notion of “internal motion”. In (13b), on the other hand, John is engaged in motion external to the *PLACE* identified by the park, and the *figure* is some path defined functionally as: \( \lambda p[\text{around}(p, \text{the\_park})] \).

The abstract syntax \( \text{ASyn}_{\text{isoSpace}} \) of ISOSpace specifies the value of the relation type \( \rho \) to be \( \text{CDATA} \), allowing any possible values. In a concrete syntax proposed here, we specify this value to be \( \text{TRAVERSE} \), as defined above, a single value for each of the \( <\text{moveLink}> \) instances. If a mover \( x \) traverses a path \( p \), then \( x \) goes through \( p \) by being located at its begin-point, midpoints, or endpoint, sequentially as time progresses.

### 5 Conclusion

In this paper, we propose a reformulation of the *MOVELINK* tag in ISOSpace, motivated by two major concerns: it currently fails to satisfy the conditions on link structures in abstract syntax, as defined in Bunt et al. (2016); and it contributes no additional information to the annotation beyond the identification of the semantic roles involved in motion. Since this is information that is already annotated or accounted for by other specifications, it was seen as largely uninformative. The new formulation of *MOVELINK* structures it as a relation between a *MOVER* and the *EVENT_PATH* created by the traversal in the movement event. This accords with both Talmy’s typological observations regarding how motion is encoded in language, as well as the qualitative spatial interpretation of motion provided in Pustejovsky and Moszkowicz (2011) and Mani and Pustejovsky (2012).

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4In Mani and Pustejovsky (2012), the *mover* is treated as the figure of a movement link.
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