Wayfinding Choremes 2.0 – Conceptual Primitives as a Basis for Translating Natural into Formal Language

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Abstract. Continuous spatial and temporal information is cognitively segmented into meaningful units that we refer to here as conceptual primitives; since we are focusing on routes in street networks, we define these primitives more specifically as *wayfinding choremes*. For the case of movement patterns in constraining environments such as driving around in street networks the wayfinding choremes are coupled with decision points that can offer alternative path choices or structure and/ or confirm a specific part of the route. To be able to analyze these choremes we have conducted a series of experiments in the past that focused on how a movement pattern can be characterized linguistically. Here, we apply the insights we gained to analyze and interpret linguistically characterized movement patterns to questions of automatically identifying movement patterns in text. That means we are analyzing verbal route directions and identify wayfinding choremes to infer the underlying movement patterns. To support our long term goal of automatic extraction of wayfinding choremes from text documents, we formally specify a taxonomy of wayfinding choremes as a first step for an ontological analysis. We will present the theoretical underpinning, tools, first results, and our perspectives on the linguistic analysis of movement patterns in this contribution. We hope to contribute to a better understanding of how natural language descriptions and formal characterizations can be closer related and can inform the automatic extraction of movement patterns from text.

Introduction

Movement patterns, of individual cognitive agents but also of groups of agents, are potentially continuous over time and space. Cognitively, movement patterns are processed into meaningful (conceptual) units, referred to here as wayfinding choremes (i.e. conceptual primitives) {Brunet 1987 #749}{Klippel 2003 #344}. The term primitive does not indicate an atomic component but a foundational one for the characterization of movement patterns from a cognitive perspective {Mandler 1992 #565}. In the following we are focusing on movement patterns of cognitive agents in constraining networks such as street networks (however, parts of this approach can be used in the broader context of characterizing movement patterns generally). The conceptual primitives identified cognitively in movement patterns can be referred to linguistically in manifold ways. For movement patterns in constrained networks references are primarily about the combination of actions taking place at decision points. Decision points do not have to involve a change in direction nor do they require the option of changing the direction. For example, *you will pass a church*, enables the agent to decide they are still on track.

The manifold possibilities for natural language to characterize a conceptual primitive as part of a movement pattern makes it necessary to establish a systematic characterization of movement patterns in constraining networks. We therefore establish an ontological characterization of linguistically characterized movement patterns as found in route directions on the web on the basis of previous work on cognitively ergonomic route directions to bridge the gap between the conceptual and the linguistic characterization of movement patterns. The key elements of this ontological characterization are: a special focus of origin and destination {Klein 1979 #199}{Klein 1982 #1453}, a comprehensive concept of landmarks and how landmarks are used to anchor but also structure movement patterns {Couclelis 1987 #1639}{Hansen 2006 #2334}, and inference rules necessary to resolve underspecified information. The ontology is further specified on the basis of text analysis of route directions found on the web. Web based route directions are a realization of a linguistically characterized movement patterns that can be characterized between natural spoken language and stylized route directions generated by a navigation service. The ontological characterization has two purposes: On the one hand, the ontology allows for characterizing movement patterns described linguistically as conceptual primitives. On the other hand, the ontology will be the basis for natural language processing and will be integrated into a framework for contextual natural language analysis of movement patterns.

Wayfinding Choreme Theory

The wayfinding choreme theory was designed to model route knowledge on the conceptual level by identifying conceptual primitives that underlie wayfinding behavior as well as graphical and verbal route directions. Wayfinding choremes are separated into I-wayfinding choremes and E-wayfinding choremes, inspired by the Chomskian distinction into I-language and E-language {Chomsky 1986 #1272}. This distinction is necessary to distinguish between the conceptualization of an actual movement pattern, which also can be an imagined one, and how this movement pattern is characterized in an external representation such as expressed in linguistic (or graphic) form {Jackendoff 1990 #2539}. Figure 1 shows an example of why this distinction is indeed necessary by juxtaposing a movement pattern with several possible verbalizations {Klippel to appear #807}.

aand..äh.. continue down straight until you co..come to a ..eh .. SIX-intersection.. ROAD.. and you'll take thee.. you won.. you will NOT go STRAIGHT, you will go..you will go LEFT on the THIRD (ping).. the third ehm.. intersection. and travel down.. THAT and reach... the destination.

and FOLLOW that street ..down through another ... through a SIX-POINT intersection and continue on..just past the.. FedEx-Office.. on your left.

and then .. go straight for a while and there'll be..there is gonna be another BIG intersection .. don't make.. the comPLETE left but .. veer .. LEFT .. and you should see .. a FEDEX (ping) building .. aand .. that's about where you STOP. (haha)

and then.. you should be.. go down straight.. towards the FedEx.. and then STOP..shortly after that.

Figure 1. Intersection with four verbalizations (Klippel et al., to appear).

I-wayfinding choremes are defined as abstract mental concepts that underlie verbal and graphical route directions and wayfinding

E-wayfinding choremes are the externalization of abstract mental concepts that are rendered more precise given a specific situation.

To be able to characterize conceptual route knowledge as a formal language, in its first realization the wayfinding choremes theory was used to model route knowledge when information regarding a specific route is available, for example, as the result of using a routing algorithm such as the shortest or fasted route {Dijkstra 1959 #59}. In this case it is important to first analyze the route into conceptually primitive movement patterns to be able to relate specific movement patterns to a natural language description. The wayfinding choreme theory supports combination of conceptually primitive movement patterns into spatial chunks {Klippel 2003 #1333}{Klippel accepted #2939}, i.e. to change the granularity on which a movement pattern is characterized. This support for chunking as well as other elements in the theory directly reflects results obtained from behavioral experiments on verbal and graphical route directions {Denis 1997 #1650}{Lovelace 1999 #1464}{Allen 2000 #260}{Tversky 1999 #377}.

Originally, the wayfinding choreme theory took a route (for example, calculated by a navigation service) as input and processed the route information into meaningful units that then could be associated with a linguistic description. This restriction, i.e. from a calculated route via conceptual primitives to natural language description, was placed on the first formal part of the wayfinding choreme theory, not on the theory as such. In this paper, we will provide a version of the wayfinding choreme theory that is closer to the original idea of abstract mental concepts that underlie verbal and graphical route directions. This will allow us to infer from linguistically characterized movement patterns the route they are related to.

We will base our approach on a corpus based analysis extracted from route directions found on the web. While these route directions are primarily targeting route directions for generalized cognitive agents, it can be shown that the resulting directions exhibit many of the characteristics that have been discussed more recently, too, i.e. how the familiarity with a certain environment can change the level of granularity in route directions and how information of a movement pattern in a spatially constrained network is encoded in natural language by making use of characteristics of the movement pattern as such and information/knowledge found in the environment.

Primer: Conceptual primitives

It is important to clarify what is meant by conceptual primitives. As noted above, a conceptual primitive is not to be interpreted in the sense of being atomic {Mandler 1992 #565}. A conceptual primitive is not the smallest possible distinction of an action that occurs during wayfinding and route following. For example, a set of primitive wayfinding choremes for direction changes at intersection {Klippel 2003 #344} was a first, and necessary step to translate route information to actual route directions and to establish a basis for cognitively ergonomic route directions that integrate the ingredients found in human generated route directions without mimicking human errors. From a more general perspective, we summarized the principles of cognitively ergonomic route directions as follows ##Klippel to appear##:

- they are qualitative, not quantitative,
- Allow for different levels of granularity and organize spatial knowledge hierarchically,
- Reflect cognitive conceptualizations of directions at decision points,
- Chunk route direction elements into larger units to reduce cognitive load,
- use landmarks to:
    - disambiguate spatial situations
    - anchor turning actions,
    - and confirm that the right actions have been taken.
- present information in multimodal communication systems allowing for an interplay of language and graphics, but respecting the underlying conceptual structure
- allow for an adaptation to the user's familiarity with an environment as well as personal styles and different languages.

From this gathering of ingredients of cognitively ergonomic route directions and from the knowledge of analyzing route directions generated by human participants and the more stylized route directions found on the web, we think it is necessary to point out the meaning of primitive in several parts of cognitive science that is also applicable to the wayfinding choremes theory: *Conceptual primitive has to be read in the sense that it is foundational to a human cognizer and not in the sense that they are atomic*. This definition can be found, for example, in literature on image schemata (Mandler, 1992).

The critical part to notice from the above is that conceptual primitives can occur on different levels of granularity. For the case of wayfinding choremes, the goal has not been to be as abstract as research on image schemata (Raubal, Egenhofer, Pfoser, & Tryfona, 1997) and to use the probably most abstract description possible. The goal has been to be specific enough to enable modeling of route directions and wayfinding behavior for real routes and to be able to generate cognitively ergonomic route directions. Or, as in the present paper, to use the concept of conceptual primitives to support analysis of linguistic route directions (found on the web).

An 'Ontological' Characterization of Linguistically Described Movement Patterns

Creating ontologies on the basis of a natural language analysis is a challenging (some may say impossible) task. The reason is that natural language expressions are often highly ambiguous and language constructs are too flexible and can occur in a variety of realizations. Take as an example work by Bennett and Agarwal (Bennett & Agarwal, 2007) who analyzed natural language expression related to the concept of *place*. While they were able to delineate a first semantic framework for the concept of place, with respect to the possibilities of how natural language refers to place they conclude: "When we began this work, we believed we could proceed directly to formulate a general logical theory of the concept of place. However, we soon found that the huge variety of different ways in which place enters into language made it impossible to achieve a simple theory that covered all these modes. Thus we were driven to a detailed analysis of the many linguistic expressions of place concepts and their semantic content." (Bennett & Agarwal, 2007, p. 94) (found in Bateman 2008)

The solution that they offered is a semantic analysis of individual linguistic expression of place. Bateman (2008) draws some interesting conclusions from this problem with respect to his own work. These conclusions start with a statement that "[…] it is necessary to cleanly separate the linguistic semantics of space from the non-linguistic, situation-specific interpretation of space." (Bateman, 2008, p. 2) In this spirit Bateman and coworkers have extended the General Upper Model (Bateman, Hois, Ross, Tenbrink, & Farrar, 2008). They consider language itself as a contributor to an ontology-like organization and conclude: "The spatial configurations thus captured contain precisely the degree of formalization required to explain the linguistic options taken up without overcommitting in terms of the physical or conceptual spatial situations that may be compatible with those commitments. The result is then what we may term a linguistically-motivated ontology specifically tailored to the requirements of spatial language and which, as a consequence, is also particularly well suited for natural language processing" (Bateman, 2008, p. 2)

Our approach is, to some extent, following this work but is more strongly focusing on the underlying conceptualization of a movement pattern in a constraining spatial network. The flexibility that language exhibits can, of course, be observed in route directions, too. Nonetheless, while referred to in different ways, not every linguistic description requires a new concept. For this specific domain, we believe that it is possible to characterize movement patterns in constrained networks on both the conceptual and linguistic level in harmony.

Ontological characterization

For our linguistically/conceptual/ontological characterization of movement patterns we analyzed movement patterns described linguistically in route directions found on the web. This kind of movement description offers an interesting type of linguistic text. They are not as varied as spoken natural language text but they are also not as stylized as route directions provided by navigation services (see Figure 2).

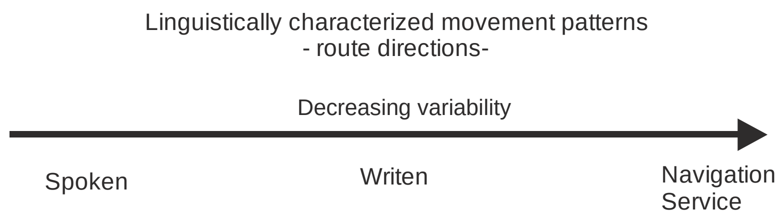

Figure 2. Variability in linguistically characterized movement patterns.

For our analysis and long term goal of automatically extracting and geo-locating movement patterns, we identified 12,000 web-pages that contain route directions. These web pages were obtained by crawling the web using key words such as turn left (in combination with others). From these 12,000 web pages we randomly sampled 50 documents to hand tag (note that sometimes documents contained more that one route direction).

The tagging tool

We are systematically hand tagging a sample corpus of documents to support both development of a route direction taxonomy and creation of a standard against which to test our computational algorithms. To facilitate this hand tagging effort and to increase consistency with which the process is carried out, we developed an interactive hand tagging tool. Figure 3 shows the two primary panels in this tool, a document view and a schema/tag view.

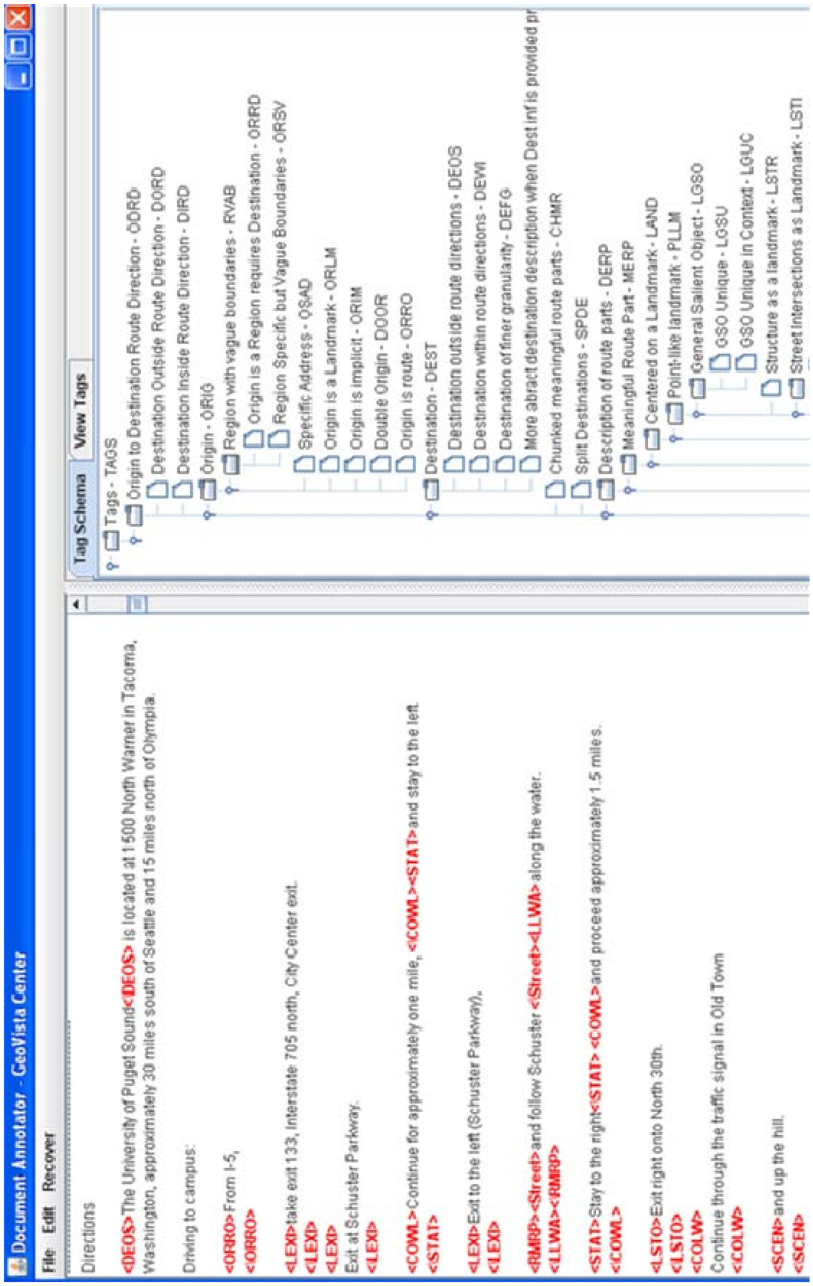

Figure 3. Screen shot of the tagging tool. The left side shows part of a textual route direction extracted from a website. The right side shows part of a taxonomy of meaningful route parts.

As noted, one of the main purposes of the tagging tool is to support creation of a taxonomy of route direction concepts (as shown on the right part of Figure 3). This taxonomy of route direction elements (described in some detail below) is the basis of our ontological characterization and can be exported as an OWL file to be further processed using ontology editors such as ConceptVISTA.

The taxonomy

Given the space restrictions, we only discuss some basics components here. The first distinction we make follows literature on route directions (Klein, 1979; Klein, 1982) and distinguishes the *origin* and *destination* from the main body of the route directions. This distinction is necessary as both, origin and destination, require special treatments in manifold ways.

Origin

While in route directions generated by navigation services the origin is either a directly specified address or an assumed one (e.g., some central part of a city), route directions found on the web exhibit a variety of kinds of origins that are interesting with regard to the way they encode spatial information and requirements to properly infer the correct location of the origin. For example, in our taxonomy we distinguish:

- Origins
  - Origins as regions
    - Specific pseudo crisp boundaries
    - Specific vague boundaries
    - Unspecific – requires destination
  - Origin as address
  - ……

These categories and their relevance for inferring spatial information from them are described below briefly.

Origins in route directions on the web are often specified as regions. These regions can be pseudo crisp such as *from Tennessee.* While Tennessee itself has, of course, a crisp boundary, the name used in route directions most likely does not adhere exactly to these boundaries and can be seen more like a special case of the inherently vague but specific boundaries. An example for the latter would be *from downtown Pittsburgh*. In this case the region itself is vague, i.e. downtown is not exactly defined, nonetheless, downtown Pittsburgh can at least be roughly located on a map.

The last example we mention in this category briefly are origins that are vague regions and that require knowing the destination. Examples of this category would be *from the North*. To understand and properly interpret and geo-locate an origin like this it is necessary to know where the destination is located (in reality though, any location along the route would be a proper substitute for the destination information).

Meaningful route parts

Our definition of meaningful route parts, i.e. wayfinding choremes, centers on a broad concept of *landmarks*. Landmarks are not defined solely in the classical sense, i.e. point-like salient objects, but any kind of object (point-like, linear-like, area-like) and various kinds of saliency. Our saliency concept therefore follows a definition of *landmarkness* by Presson and Montello (1988) that everything that sticks out from the background can be regarded as a landmark.

As an example, for meaningful route parts that are centered on a point-like landmark, we make the following distinctions in our taxonomy:

- Point-like landmark
    - General salient object
        - General salient object unique
        - General salient object unique in context
    - Structure as a landmark
    - Street intersection as a landmark
        - Both streets explicitly mentioned
        - One street explicitly mentioned one implicit (contextual)
    - Exits
    - ……

Here, we discuss just the first distinctions that we make, which are extensions of our previous work in this area (Hansen, Richter, & Klippel, 2006). Point-like landmarks can be general salient objects. Some of these objects are unique on a larger scale primarily induced through a name. An example would be *Blueberry Bridge*. (It is not possible to exclude the possibility that more than one Blueberry Bridge exists, but this will typically be sufficient to uniquely identify. To complete the geo-locating process, establishment of a spatial context is necessary; for example it may be necessary to know origin and destination and other route parts. Other general salient objects are unique only in context, for example, *at the end of the bridge*. In this case it is not possible to look up the location of the bridge and additional spatial information about the route is necessary to locate the bridge.

Conclusions and outlook

In this contribution we addressed the issue of transducing natural language into formal language by analyzing natural linguistic route directions as they can be found on websites. This kind of route directions is appealing for analysis as they are constrained in two ways: First, the spatial environment is of constraining character and thereby easing the interpretation of natural language expressions; second, compared to spoken language web route directions exhibit less variability (nonetheless they are not as monotonous as route directions generated by navigation services). The core of our analysis is the idea of conceptual primitives of route directions and route following behavior that we termed *wayfinding choremes* (Klippel 2003). Wayfinding choremes are primitives in a cognitive, foundational sense. Our long term goal is the automatic analysis of linguistically encoded movement patterns. The first step of our analysis is aiming to identify wayfinding choremes automatically in route directions. For this purpose we developed a taxonomy of wayfinding choremes on the basis of previous work and refined by an analysis of a sample of web documents containing route directions. The second step is twofold: The taxonomy will be ‘enhanced’ by adding axiomatic constraints to its components as a prerequisite for developing an ontological characterization. This ontology will be used to inform an automatic linguistic analysis. Additionally, we will work on characterizing the spatial information about a movement pattern encoded in a wayfinding choreme formally by analyzing the linguistic description as such and additionally using georeferenced text parts for adding additional constraints.

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