A Geo-Ontology Design Pattern for Semantic Trajectories

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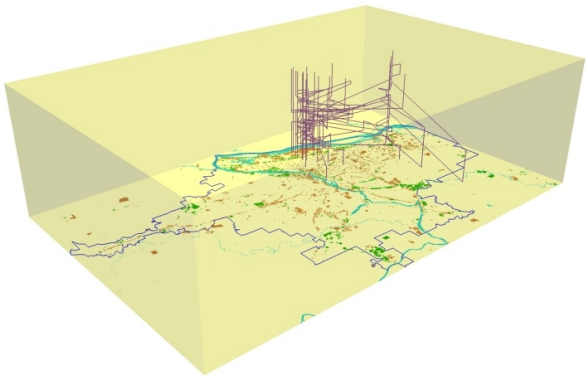
Outline

- Introduction
- Conceptual Foundation
- OWL Formalization
- Applications
- Conclustions and Future Work

Introduction

- Trajectory data have been used in a variety of studies.
  - Human behavior analysis
  - Transportation management
  - Wildlife mornitoring



Introduction

- The term **trajectory** can be defined as a sparse set of temporally-indexed positions (or **fixes**) of the moving object, while its exact path between these fixes is unknown and has to be estimated.
- Some fixes have no specific meaning and are purely artifacts of the used positioning technology.
- Some other fixes denote important activities of the moving object, and researchers may be interested in annotating and classifying them– **semantic trajectories**.

Introduction

- Linked Data has become one of the choices to publish trajectory data in the past few years.
- Two approaches:
  - **Foundational ontologies**: they have been usefully applied as a common ground for geo-ontologies, but tend to be abstract and may introduce ontological commitments which are difficult to handle for laypersons.
  - **Ontology design patterns**: flexible, reusable, and self-contained building blocks that help to model reoccurring tasks. They can also be combined and ultimately aligned with foundational ontologies that act as glue between patterns.

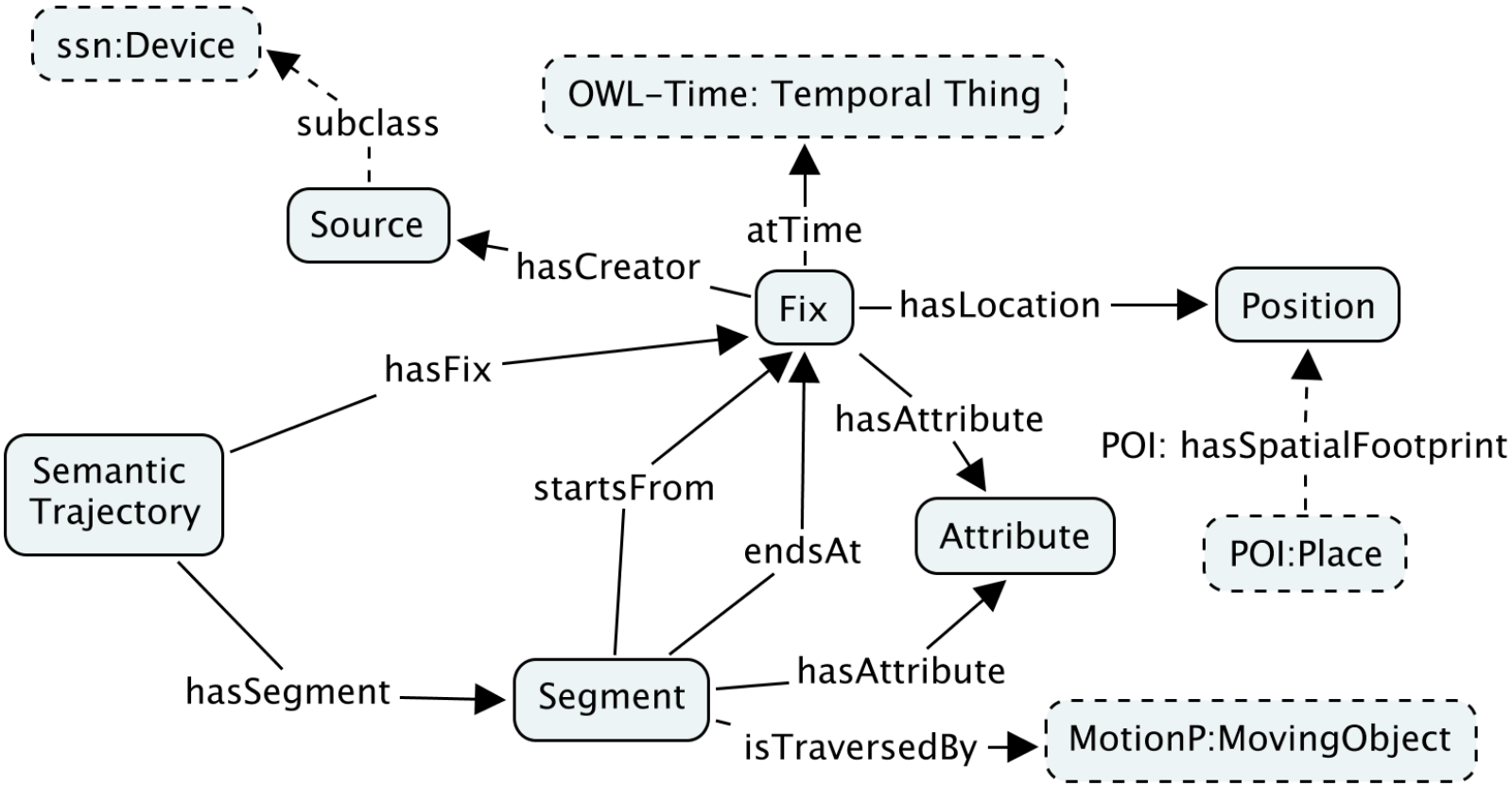
Introduction

- We propose an ontology design pattern for semantic trajectories.
- Two goals of our ontology design pattern:
  - First, it should be directly applicable to a variety of trajectory datasets, and, thus, reduce the initial hurdle for domain scientists to publish Linked Data.
  - Secondly, it should be easily extensible, e.g., by aligning to or matching with existing trajectory ontologies, foundational ontologies, or other domain specific vocabularies.

Conceptual Foundation

- *Competency questions* have been used to detect the generic use case of the design pattern.
  - "Show the birds which stop at x and y" (*spatial data*)
  - "Show the birds which move at a ground speed of 0.4 m/s" (*attribute data*)
  - "Show the trajectories which cross national parks" (*geographic knowledge*)
  - "Show the trajectories of the birds which are less than 1 year old" (*domain knowledge*)
  - "Show the trajectories captured by Gamin GPS" or "show the trajectories generated by iPhone users" (*information about the data creator*)

Conceptual Foundation



OWL Formalization

- A fix is defined as a spatiotemporal point $\{x_i, y_i, t_i\}$ which indicates the location of a moving object at an instant of time.

$$\begin{aligned} Fix \sqsubseteq\ & \exists atTime.OWL\text{-}Time{:}Temporal\ \ Thing \sqcap \exists hasLocation.Position \\ & \sqcap \exists hasFix^{-}.SemanticTrajectory \end{aligned} \tag{1}$$

OWL Formalization

- A segment is defined by exactly two fixes, a starting fix $\{x_i, y_i, t_i\}$ and an ending fix $\{x_j, y_j, t_j\}$.

$$\mathit{Segment} \sqsubseteq \exists \mathit{startsFrom}.\mathit{Fix} \sqcap \exists \mathit{endsAt}.\mathit{Fix} \tag{2}$$

$$\top \sqsubseteq \leq 1\mathit{startsFrom}.\top \tag{3}$$

$$\top \sqsubseteq \leq 1\mathit{endsAt}.\top \tag{4}$$

$$\mathit{Segment} \sqsubseteq \exists \mathit{hasSegment}^{-}.\mathit{SemanticTrajectory} \tag{5}$$

OWL Formalization

- The class of semantic trajectory serves as the access point for the ontology design pattern.

$$\mathit{SemanticTrajectory} \sqsubseteq \exists \mathit{hasSegment}.\mathit{Segment} \tag{6}$$

$$\mathit{hasSegment} \circ \mathit{startsFrom} \sqsubseteq \mathit{hasFix} \tag{7}$$

$$\mathit{hasSegment} \circ \mathit{endsAt} \sqsubseteq \mathit{hasFix} \tag{8}$$

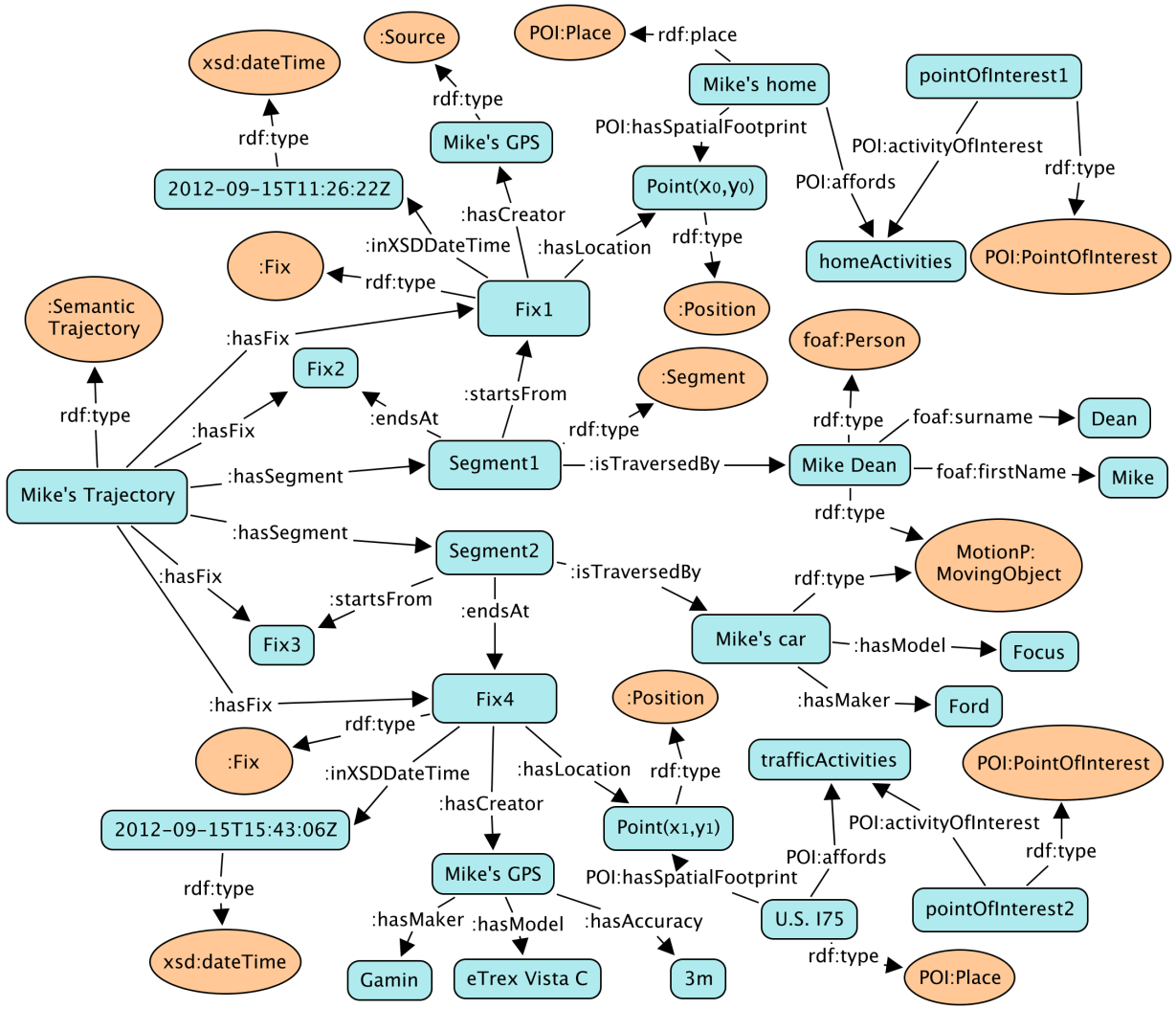
OWL Formalization

- StartingFix, EndingFix, and Stop
- Ordering Fixes within a Trajectory
- Position and Point-of-Interest
- Attribute and hasAttribute

Application

- This ontology design pattern has been applied to modelling Mike Dean's trajectory, recorded by a hand-held GPS.
- In this trajectory, Mike was traveling in two modes (walking and driving)

Application



Conclusions

- A geo-ontology design pattern for semantic trajectories have been developed in this research.
- It has the following features:
  - **Expressiveness**. The design pattern can express the trajectory's spatiotem- poral properties, geographic knowledge, domain knowledge, as well as the relations among them.
  - **Simplicity**. Only a minimal number of classes and relations are introduced, which makes the design pattern easy to understand, reuse, and extend.
  - **Flexibility**. The provided interfaces (generic classes such as Source) allow the user to integrate related knowledge according to the specific needs of the application (users can also leave interfaces open and use the pattern directly without subtyping).
  - **Scalability**. Depending on the required granularity of a particular application, the ontology design pattern can model trajectories at different scales.