

A Spatiotemporal Extent Pattern based on Semantic Trajectories

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Abstract. While the concept is certainly not new to ontology modeling, we have not been able to identify a published pattern on the fundamental notion of *spatiotemporal extent*, which captures the dimensions of things as they move through space and time. We present such a pattern, based on an already published pattern for semantic trajectories.

1 Introduction and Motivation

Most things are not stationary. Even apparently immovable things like cities and countries change their spatial extent over time, be it due to politics, natural disasters, wars, or changing geographic and economic factors. A more natural example may be an event. Oceanographic cruises, as pointed out in [3], can be understood as events, namely as space-time paths. A parade moves. A hurricane moves. The Renaissance occurred in different places at different times, as did the Bronze Age. The World Chess Championship Match 1990 moved. It was held in two parts, in two different locations, namely New York (October 8 to November 7) and Lyons, France (November 26 to December 30), and we note in addition that its temporal extent was discontinuous.

Yet, in ontology modeling we often assume, rather naively, that things are stationary. The Simple Event Model does it [1], and indeed in many cases assuming that things are stationary will be sufficient for many application scenarios. Others, such as [6], discuss and address the issue.

In any case, assuming that a separation of time and space may often be an oversimplification, we realize that there seems to be no prominent (or even published) proposal for a pattern describing simple spatio-temporal extents. We will address this in this brief paper.

2 The Pattern

We are going to model a spatiotemporal extent as a set of generalized trajectories which cannot have temporal overlap.¹ We use this approach because we have a

¹ OWL encoding is at <http://krisnadhi.github.io/onto/spatiotemporalextent.owl>. ODP Portal submission is at <http://ontologydesignpatterns.org/wiki/Submissions:SpatioTemporalExtent>

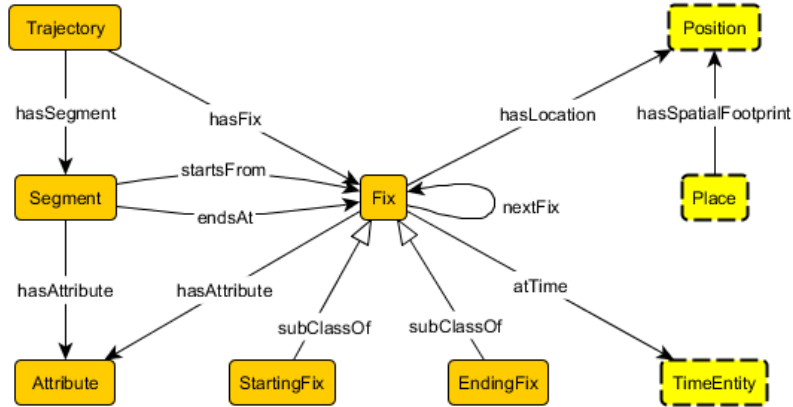


Fig. 1. Partial class diagram of the Trajectory Pattern from [2]. The dashed boxes indicate classes which are themselves (external) patterns, i.e., they need to be specified using a concrete module, or partial ontology.

strong and versatile pattern for trajectories at hand [2] which can be used for this purpose. Figure 1 depicts a class diagram for the main relationships in the trajectory pattern from [2],² which we refer to the reader for more detail.

A few remarks are in order, though, regarding the trajectory pattern. A trajectory in this model is thought of as a sequence of fixes which are connected by segments. There is exactly one starting fix and exactly one ending fix. Each fix has a temporal extent and a location, modeled as a position.

For our purposes, we may not think of a location as being one specific position. We rather think of it as a spatial extent, e. g., a *Place*, which can be represented, e.g., as a region using a polygon on the Earth’s surface. There is no need to make any additional changes to the pattern.

The resulting class diagram is depicted in Figure 2. Axioms are inherited very simply from the trajectories pattern which was reused, in addition to the following, which indicate that every spatiotemporal extent has to have at least one trajectory, that the scoped range of `hasTrajectory` is indeed the class `Trajectory`, and that the range of `hasSpatioTemporalExtent` is a spatiotemporal extent.

$$\begin{aligned}
 \text{SpatioTemporalExtent} &\sqsubseteq \exists \text{hasTrajectory.Trajectory} \\
 \text{SpatioTemporalExtent} &\sqsubseteq \forall \text{hasTrajectory.Trajectory} \\
 \top &\sqsubseteq \forall \text{hasSpatioTemporalExtent.SpatioTemporalExtent}
 \end{aligned}$$

There is a another axiom which would need to be added, however this axiom requires some form of temporal reasoning and thus cannot be expressed naturally

² OWL encoding is at <http://krisnadhi.github.io/onto/trajectory.owl> with slight modification in the axiomatization compared to the one provided in [2].

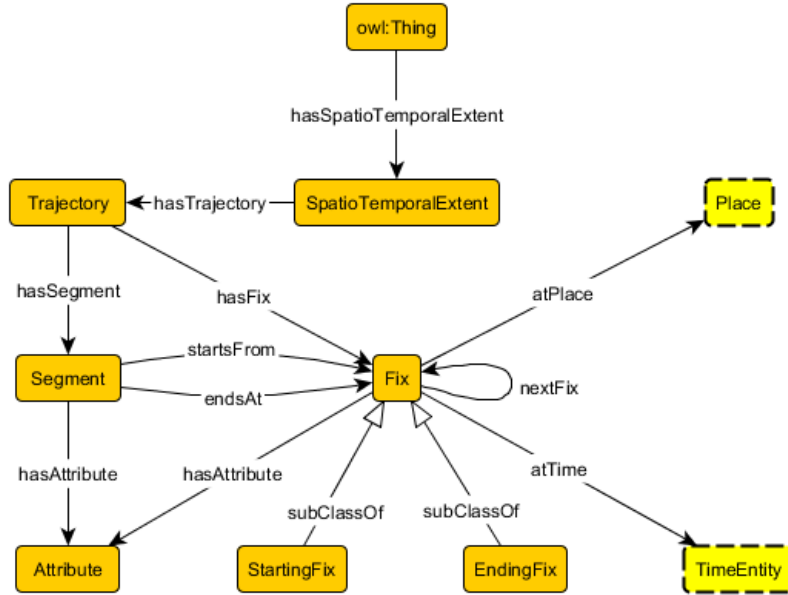


Fig. 2. Class diagram for the Spatiotemporal Extent pattern.

in the Web Ontology Language (or, for that matter, in first-order predicate logic). The axiom expresses that any two different trajectories for the same spatio-temporal extent cannot have temporal overlap.

3 Further Discussion

Let us look at two specific cases. The first is the situation where the spatial extent is in fact stationary. In this case, there would e.g., be only two fixes, the starting fix and the ending fix, and they would share the same place. The resulting trajectory would have only one segment. Schematically, this is depicted in Figure 3 for the 2016 World Chess Championship.

Of course, for a spatiotemporal extent which is a stationary trajectory, the use of our pattern seems to produce significant overhead in terms of triples as compared to a straightforward model which separates spatial and temporal aspects. This is a typical situation which calls for shortcuts to be used in the simplified case. In Figure 3, the three dashed red arrows indicate such shortcuts, and they can be axiomatised using three rules in Figure 4, in the case of stationary trajectories. For more discussions and insights regarding shortcuts, see [4,5].

We can also indicate a discontinuous temporal extent, such as in the case of the 1990 World Chess Championship Match mentioned earlier. In this case, we

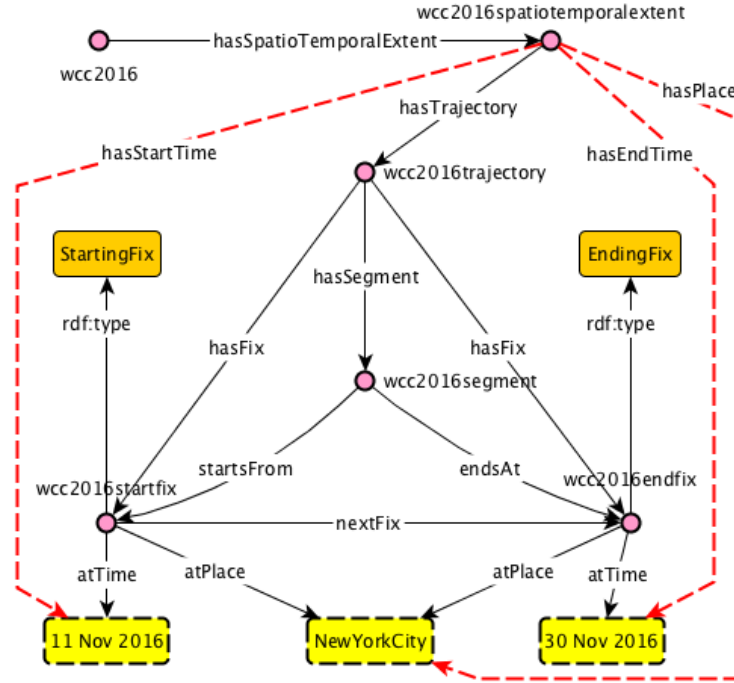


Fig. 3. Example for stationary trajectory: World Chess Championship 2016. The dashed red arrows indicate so-called shortcuts, which are discussed in the text.

would still assign one spatiotemporal extent to the event, but the spatiotemporal extent would in turn have two (stationary) trajectories assigned to it. Schematically, this is depicted in Figure 5.

Examples for non-stationary trajectories can be found e.g. in [2,3].

4 Conclusions

With the pattern presented herein, we have addressed a rather fundamental gap in the set of available patterns, and have provided a spatio-temporal extent pattern based on a previously described and applied semantic trajectories pattern. We have also illustrated how the pattern can be used in the case where the spatio-temporal extent is in fact stationary.

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$$\begin{aligned}
& \text{SpatioTemporalExtent}(x) \wedge \text{hasTrajectory}(x, y) \wedge \text{hasFix}(y, z) \\
& \quad \wedge \text{StartingFix}(z) \wedge \text{atTime}(z, w) \rightarrow \text{hasStartTime}(x, w) \\
& \text{SpatioTemporalExtent}(x) \wedge \text{hasTrajectory}(x, y) \wedge \text{hasFix}(y, z) \\
& \quad \wedge \text{EndingFix}(z) \wedge \text{atTime}(z, w) \rightarrow \text{hasEndTime}(x, w) \\
& \text{SpatioTemporalExtent}(x) \wedge \text{hasTrajectory}(x, y) \wedge \text{hasFix}(y, z) \\
& \quad \wedge \text{atPlace}(z, w) \rightarrow \text{hasPlace}(x, w)
\end{aligned}$$

Fig. 4. Shortcut rules for the dashed red arrows in Figure 3.

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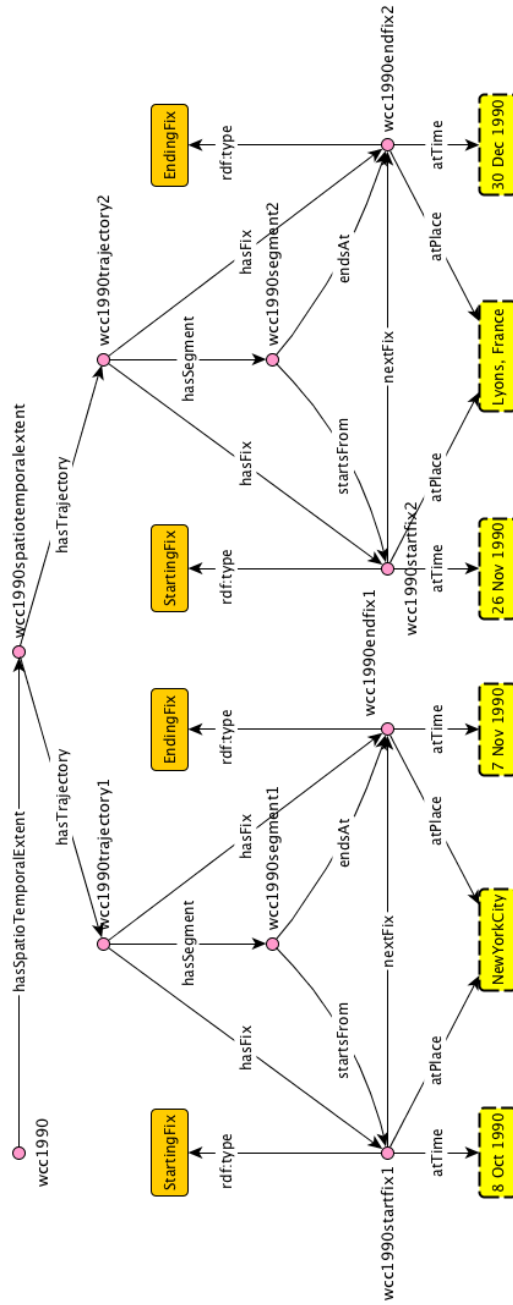


Fig. 5. Example for discontinuous temporal extent: World Chess Championship 1990.