A Pattern for Periodic Intervals

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Abstract. Non-convex intervals allow identifying periodic intervals with gaps between them (e.g., "every Wednesday"), while convex intervals are those that are not composed of "separate pieces" (e.g., "from 1st April 2014 to 30th April 2014"). Non-convex intervals consist intuitively of some (maximal) convex subintervals with convex gaps in between them. In this paper, we describe an ontology design pattern to represent *periodic intervals* that are a specific case of non-convex intervals in which the period between its subintervals and the duration of such subintervals are constant.

Keywords: Ontology design patterns, knowledge representation, ontology, time interval, periodic interval, interval.

1 Introduction

The temporal dimension affects almost every domain modelling or application, for example every purchase has a date for the ordering and might have a date for the deliver, the different types of governments or wars are delimited on time by temporal points or intervals, etc. Due to its importance and presence time theories have been developed over the years and different time ontologies have been also modelled [2, 5].

Time intervals can be seen as the time between two time points (e.g., "in which period of time the Mozart concert series happen in London? From October to February"). Time intervals can be divided into convex and non-convex. The first ones (convex intervals) are those that are not composed of "separate pieces" (e.g., a journal paper call is open during a gapless time interval); while the second ones (non-convex intervals) refer to periodic intervals with gaps between them (e.g., every working day) [2]. In other words, non-convex intervals are those that use time units in a repetitive way or refer to recurring periods [1]. This type of time periods occurs naturally among systems requirement description. For example, when a semantic system to manage the Football Champions League has to be built it is need to represent that such a league takes place "every year from September to May".

Temporal concepts (e.g., intervals, instants, temporal units, etc.) and the relations (e.g., has end, inside, unit type, etc.) holding between them have been modelled in the context of the W3C along the OWL-Time ontology[1] [3]. However, periodic intervals, which are a specific case of non-convex intervals where all the subintervals have the

[1] http://www.w3.org/2006/time#

same duration and all the "gaps" between subintervals have a constant duration, are not taken into account explicitly within the OWL-Time ontology. For this reason, we propose an ontology designed pattern, called **Periodic Interval**, which extends such an ontology about time in order to represent periodic intervals. It should be noted that one could represent the intervals shown in Figure 1 using the OWL-Time ontology. One could represent separately the intervals I_{21}, I_{22} and I_{23} and establish that they are inside I_2 (same for I_3). However, the *Periodic Interval* pattern takes advantage of the fact that (a) the durations of I_{31}, I_{32} and I_{33} are equal and (b) the gaps between them are also equal. For this reason, this pattern optimizes the formalization of this kind of intervals, called periodic intervals, as there is no necessary to define as many subintervals as the non-convex interval is composed of.

All in all, the goal of this pattern is to represent non-convex intervals where the duration of all internal intervals is constant and they are equally separated in time, that is, the duration of the "gaps" between intervals is also constant. Thus, this ontology design pattern allows representing periodic intervals.

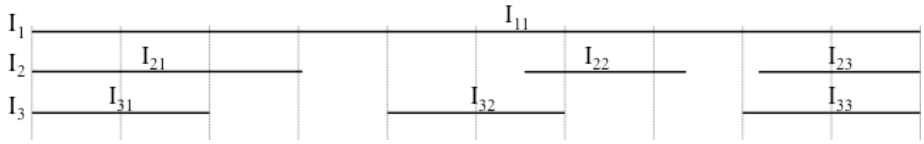

Figure 1. Non-convex interval examples

The structure of the paper is the following. Section 2 describes the periodic interval pattern and its relation with the OWL-Time ontology. Section 3 presents some use cases where the proposed pattern could be applied. In Section 4 we expose the related patterns and models. Finally, Section 5 presents some concluding remarks.

2 Describing the Periodic Interval Pattern

As it can be observed in Figure 2, the class "Interval" defined in the OWL-Time ontology has been extended within this pattern[2] by means of the class "PeriodicInterval". This concept has been created in order to define periodic intervals. These intervals are defined by four elements, namely, its **beginning**, its **end**, the **duration of each subinterval** and the **duration of the period**, that is, the gaps between subintervals. In order to model the beginning and end of the interval, we have reused the relationships "owl-time:*hasBeginning*" and "owl-time:*hasEnd*" already defined in the OWL-Time ontology. By taking advantage of the concepts and relations already defined in the OWL-Time ontology instead of creating new ones we both promote the reuse of existing models and avoid the inclusion of unnecessary complexity within the pattern being developed. The durations of the subintervals and the period between them have been modelled by means of the relationships "*hasIntervalDurationPerPer-*

[2] The URI for the periodic interval pattern is `http://odp.linkeddata.es/PeriodicInterval#`, which provides the OWL code for the proposed pattern.

iod" and "*hasPeriod*" respectively. Both relationships are defined between the concepts "*PeriodicInterval*" and "*DurationDescription*" and are extensions of the property "owl-time:hasDurationDescription" defined in the OWL-Time ontology. These extensions are highlighted in Figure 2 in two ways, first, identifiers for new terms are in bold letter and second, new terms are shown with no prefix before their identifier, while prefixes are included for the reused terms.

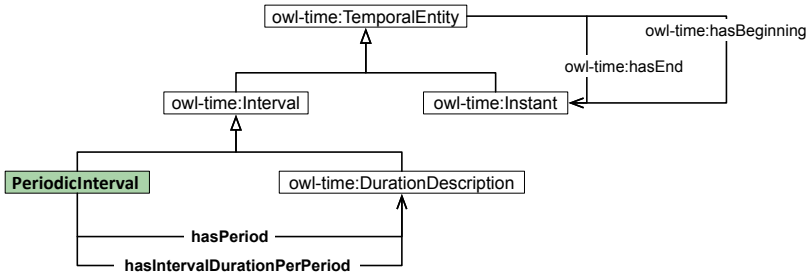

Figure 2. Periodic interval pattern

The classes and property declarations as well as domain and range definitions for the proposed patter can be found in the following snippet containing the OWL code in turtle serialization. This snipped contains the new classes and properties defined in the pattern as well as the ones defined in the OWL-Time ontology that are needed in order to instantiate the presented pattern.

```
@prefix : <http://odp.linkeddata.es/PeriodicInterval#> > .
@prefix rdfs: <http://www.w3.org/2000/01/rdf-schema#> .
@prefix time-owl: <http://www.w3.org/2006/time#> .
@prefix owl: <http://www.w3.org/2002/07/owl#> .

:hasIntervalDurationPerPeriod a owl:ObjectProperty ;
      rdfs:label "has interval duration per period"@en ;
      rdfs:domain :PeriodicInterval ;
      rdfs:range time-owl:DurationDescription ;
      rdfs:subPropertyOf time-owl:hasDurationDescription .

:hasPeriod a owl:ObjectProperty ;
      rdfs:label "has period"@en ;
      rdfs:domain :PeriodicInterval ;
      rdfs:range time-owl:DurationDescription ;
      rdfs:subPropertyOf time-owl:hasDurationDescription .

:PeriodicInterval a owl:Class ;
      rdfs:label "Periodic interval"@en ;
      rdfs:subClassOf time-owl:Interval .

time-owl:hasDurationDescription a owl:ObjectProperty .

time-owl:DurationDescription a owl:Class .

time-owl:Interval a owl:Class .
```

```
time-owl:Instant a owl:Class .

time-owl:hasBeginning a owl:ObjectProperty ;
       rdfs:domain time-owl:TemporalEntity ;
       rdfs:range time-owl:Instant

time-owl:hasEnd a owl:ObjectProperty ;
       rdfs:domain time-owl:TemporalEntity ;
       rdfs:range time-owl:Instant .
```

3 Conceivable Use Cases

The Periodic Interval pattern was first created in order to support some requirements defined for the mIO! ontology network[3] [4], a context ontology in the mobile environment. Some examples of functional requirement involving periodic intervals defined for the mIO! ontology are:

- *The ontology should be able to represent non-convex interval (e.g. every Monday).*
- *The ontology should be able to answer the following question "What is the period of the interval "every Tuesday of 2010? Answer: 6 days".*

As this type of requirements is very common across domains, the solution proposed in this work would be applicable to a recurrent problem, being considered therefore an ontology design pattern.

The Periodic Interval pattern can be used to express the following situations:

- Logic programming courses at *Universidad Politécnica de Madrid* (UMP) take place every Wednesday from 9:00 to 11:00 during the second semester (from February to June).
- A pharmacy whose opening hours are from 9:00 to 21:00 every day.
- General medical check-ups for babies that are when babies have 2 months old, 4 months old, 6 months old, 8 month old, 10 months old and 12 months old. Each check-up has a duration of half and hour.
- Summer courses at *Universidad Politécnica de Madrid* (UPM) hold every year during the first 20 days of July.
- Celebration of the *Nuestra Señora del Carmen* day in Santiago de Compostela (Galicia) every 16th of July.
- Episodes of each season of Games of Thrones are aired every Sunday during spring from 2011 until 2016, more precisely we could represent that each episode of the 4th season is aired each Sunday from April 6, 2014 to June 15, 2014.

The Periodic Interval pattern could be used to generate a dataset with temporal information about the episodes of different seasons of television series (such as Game of Thrones programmed in HBO (Home Box Office)). The pattern proposed in this paper allows representing temporal information about when episodes of Game of

[3] http://www.oeg-upm.net/index.php/ontologies/82-mio-ontologies

Thrones have been aired[4] from the beginning in 2011 until the present. In addition, the pattern could be applied for generating temporal information about episodes of the aforementioned television show in RDF within the HBO web page[5].

4 Related Modelling Practices

Temporal notions (e.g., intervals, instants, temporal units, etc.) have been modelled in the context of the W3C by means of the OWL-Time ontology, as mentioned in Section 1. This ontology allows representing proper intervals, that is, intervals whose extremes are different (e.g., (2013, 2014) is a proper interval, while (2013, 2013) is not a proper interval).

To represent a time interval, which is the time between two time points, we could use the Time Interval pattern[6]. This pattern models information about the date of a time interval as well as the starting and end time of the interval.

In addition, time intervals have been modelled in the Timeline Ontology[7], which can be seen as an extension of the OWL-Time ontology. This ontology describes intervals (same as in OWL-Time) and includes different types (abstract, discrete, relative, etc.).

However, at the best of our knowledge none of the aforementioned models (ontologies and patterns) allow the representation of periodic intervals, that is, intervals in which the period between its subintervals and the duration of such subintervals are constant.

5 Conclusions

Temporal notions commonly appear in almost every domain, so models that semantically represent such notions are needed. One of the most used semantic models for representing temporal concepts is the W3C OWL Time ontology. This ontology models intervals, instants, temporal units, and so on as well as the relations holding between them. However, the concept of periodic intervals, useful to represent temporal information about the celebration of St. James day in Santiago de Compostela (Galicia) every 25th of July, is not explicitly modelled within such an ontology.

For this reason, we propose an ontology design pattern called Periodic Interval. This pattern provides a mechanism to represent a specific case of non-convex intervals where the subintervals contained have the same duration and the gaps between subintervals are also constant. This pattern has been developed by mean of extending the OWL-Time ontology in order to reuse well-defined and known concepts and relationships related to time theory.

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[4] http://en.wikipedia.org/wiki/List_of_Game_of_Thrones_episodes

[5] http://www.hbo.com/#/game-of-thrones/

[6] http://ontologydesignpatterns.org/wiki/Submissions:TimeInterval

[7] http://motools.sourceforge.net/timeline/timeline.html

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References

1. Ladkin, P.B., *Time Representation: A Taxonomy of Interval Relations*. Proceedings of AAAI-86. 1986. http://aaaipress.org/Papers/AAAI/1986/AAAI86-060.pdf
2. Fernández-López, M., Gómez-Pérez, A. (2004). *Searching for a time ontology for semantic web applications*.
3. Hobbs, J. R. and Pan, F. *Time Ontology in OWL*. W3C Working Draft 27 September 2006. http://www.w3.org/TR/owl-time/
4. Poveda, M., Suárez-Figueroa, M.C., García-Castro, R., Gómez-Pérez, A. *A Context Ontology for Mobile Environments*. Proceedings of CIAO 2010. Lisbon, Portugal. 11 October 2010.
5. Fernández-López, M., Gómez-Pérez, A., Suárez-Figueroa, M.C. *Methodological guidelines for reusing general ontologies*. Data & Knowledge Engineering (ISSN: 0169-023X) Volume: 86 (242-275). July 2013.