

Level of Detail of Observations in Space and Time

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Abstract. More and more observations are available in the Sensor Web. While the issue of a syntactical integration is partly solved by standards defined by the Open Geospatial Consortium, semantic integration of the observations still forms a major challenge. Recently, the W3C suggested an ontology design pattern for observation ontologies. However, the design pattern is currently not addressing the differences in the levels of detail (LOD) of the observations. This work has identified four concepts related to LOD of observations, namely coverage, extent, spacing and observation grain. The novel contribution of this paper is an extension of the Stimulus-Sensor-Observation ontology design pattern with concepts of LOD. This extension can be used to find observation sets matching a certain LOD required by an application and, if the datasets are not available at the desired LOD, to apply appropriate (dis-)aggregation methods.

1 Introduction

Almost 30 years ago, Levin identified the issue of scale as 'the fundamental problem in ecology, if not in all of science' [4]. Following him, scale can be defined as the extent of a study. He argues that there is no single scale on which a scientific study can be conducted, but rather different scales on which observations are made and patterns are discovered. However, not just the extent of a study, but also the number and grain of observations available in a study area influence the results of a study. Recently, Goodchild [2] has stated that scale has three common notions: (i) cartographic scale means the representative fraction, (ii) scale can also be used to describe the extent of a study and (iii) scale might also be used for the resolution of a dataset. He also points out that scale is still a problematic issue in sciences studying phenomena in space and time.

Due to the many different notions of scale, we think that the term Level of Detail (LOD) is more precise to describe the resolution of a set of observations and to relate the resolution to the extent of a study. Therefore, we have extended the recently developed W3C Semantic Sensor Network Ontology (SSN-O) [3] with concepts of Level of Detail. The extension will help to answer questions like: How much of my area of interested is covered by observations? How much differs observation set 1 from observation set 2 in the level of detail? Which

methods can be applied to convert an observation set from one level of detail to another?

2 Extended Observation Ontology

As a foundation of our work, we are using the observation module from the SSN-O. Therein, an observation provides a digital representation, a result, for a stimulus in the real world which is a proxy for the observed property (see Figure 2). An observation is taken at a specific time (samplingTime; not depicted in Figure 2) and provides a property value for a feature of interest that usually also carries the spatial information. While this ontology can be used to match observation sets with, for example, different observed properties, it cannot be used to match observation sets with different LODs for the same observed property.

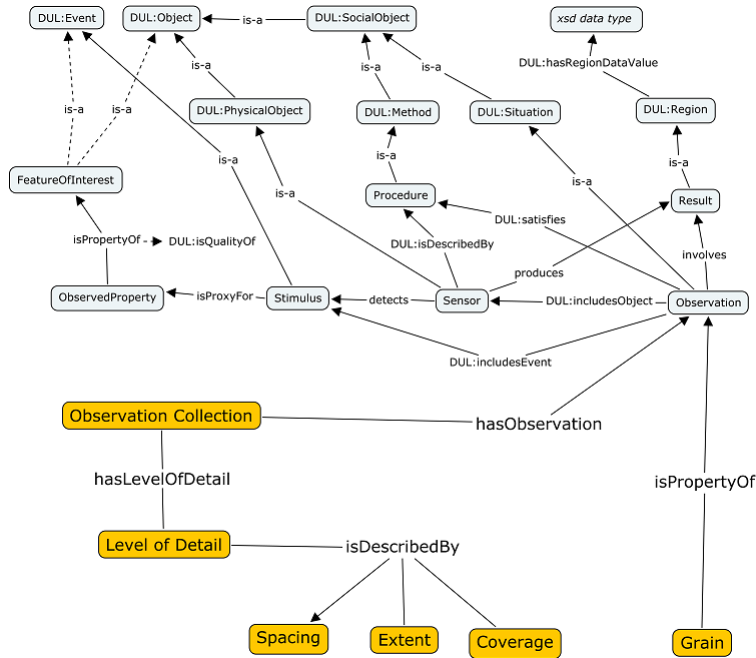


Fig. 1. A conceptual map showing the extension of the SSN ontology design pattern with concepts of grain and level of detail.

Therefore, we extend this ontology by concepts of ObservationCollection, Extent, Coverage, Grain, Spacing and LOD which are shown as yellow concepts in Figure 2. The concepts are partially following the definitions of Wu and Li [5]. *Grain* is the finest spatial or temporal unit within which homogeneity is

assumed for an observation; *extent* is the total spatial or temporal expanse of the study (i.e. observation collection); *coverage* describes the sampling intensity in space and time; it is the ratio of the sum of the grain sizes of all observations to the extent of the observation collection. *Spacing* is the mean interval between two adjacent observations. Besides the concepts of LOD, we also introduce an ObservationCollection that represents a set of observations. In our conceptualization of LOD, the LOD is a property of an ObservationCollection, while the grain is a property of a single observation. Both, LOD and grain apply, for the temporal and spatial dimension. Figure 2 illustrates the level of detail for the spatial dimension.

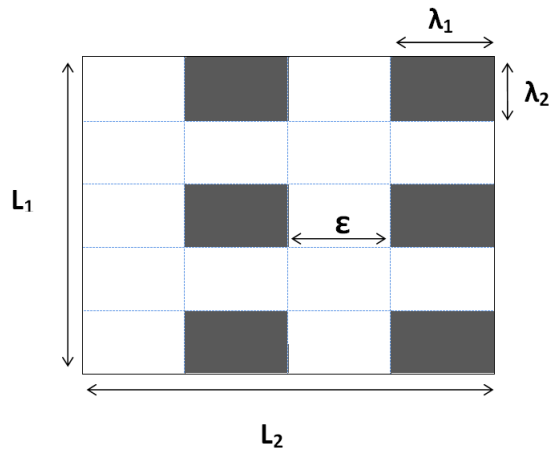


Fig. 2. A simplified view of components of scale for the spatial dimension (modified from [1]): the grain size is $G = \lambda_1 * \lambda_2$, the extent is $E = L_1 * L_2$, the spacing is $S = \epsilon$ and the coverage is $C = \frac{\text{Number of samples}}{\text{Extent}} = \frac{6}{L_1 * L_2} = \frac{6}{5 * 4} = \frac{3}{10}$.

3 Conclusions and Future Work

In order to integrate different observation sets, considering the Level of Detail (LOD) is essential. Therefore, an extension of the W3C Semantic Sensor Network Ontology (SSN-O) is proposed. The extensions defines the LOD as a property of a set of observations and can be described by its components (Coverage, Extent, Spacing). Coverage relates the Grain of an observation, which we define as the spatial and/or temporal extent of single observations, to the total extent of an observation collection. While the term scale is sometimes used in a similar notion, we propose to use the term LOD, as scale has many meanings in different contexts [?].

We plan to extend the LOD enabled observation ontology to the air quality domain. The ontology will then be applied to observation sets with varying spatial and temporal level of detail. Therefore, we use the AirBase dataset provided by the European Environmental Agency (EEA). The database contains air quality observations from all European member countries. However, the network of monitoring station varies significantly within Europe. While central europe is covered by a dense network of monitoring stations, the outer zones are usually covered with less stations. We plan to use the ontology to decide whether observations sets for certain regions are comparable with other regions. Furthermore, information about air quality is needed for decision makers at different levels ranging from local over regional to national or even European level. Thus, the data has to be provided in different LODs. Therefore, aggregation methods such as Kriging interpolation need to be applied. At the moment, the knowledge about which method to use for which observation set is provided by domain experts. We are also planning to formalize this knowledge in order to suggest or disallow aggregation methods for observation sets. Our LOD enabled observation ontology forms one part of this work.

Finally, our concept of LOD is used for the spatial and temporal domain at the moment. However, we also consider that the result values of an observation can have a certain level of detail. Therefore, we will prove whether we can use our LOD extension also for the value domain of observations.

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