PolisGnosis Project:
Representing and Analysing City Indicators

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Overview

Cities use a variety of metrics to evaluate themselves. With the introduction of ISO 37120, which contains over 100 indicators for measuring a city's quality of life and sustainability, it is now possible to consistently measure and compare cities, assuming they adhere to the standard. The goal of this research is to develop theories, embodied in software, to perform longitudinal analysis (i.e., how and why a city's indicators change over time) and transversal analysis (i.e., how and why cities differ from each other at the same time), in order to discover the root causes of differences.

Our approach is to develop the PolisGnosis Engine (Figure 1) that takes as input:

- All of the information and knowledge with respect to an indicator,
- A set of consistency axioms, and
- A set of diagnosis axioms,

and applies the axioms to determine why indicators change.

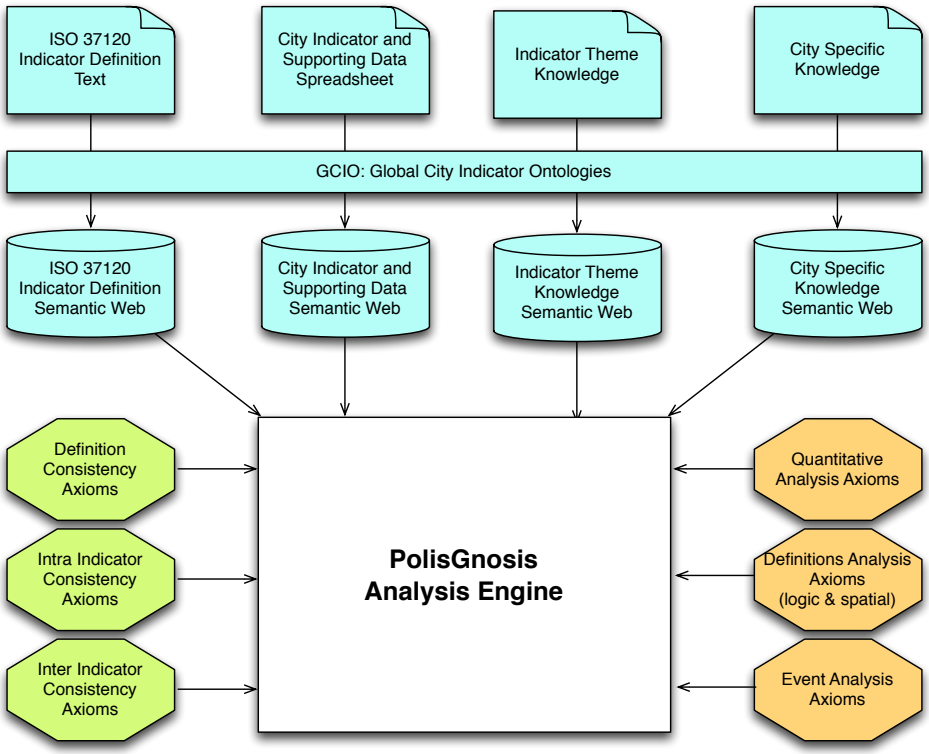

Figure 1: PolisGnosis Architecture

The blue boxes focus on the representation (i.e., Ontologies) of indicators and their supporting data. The goal being to transform existing data formats into a standard representation that can be published on the Semantic Web. The green boxes focus on consistency analysis of published indicator data to verify that it is consistent with the definitions of the indicators, and that indicators for a city over time or comparing two cities are consistent. The orange boxes focus on theories to diagnose the root causes of longitudinal and transversal differences. In the following we elaborate on these three areas and then outline the Ontology Architecture. We use as an example indicator 6.4 in the ISO 37120 standard: Primary School Student Teacher Ratio. It measures the ratio of students who attend primary public schools to teachers who actually teach at primary public schools.

Ontology Research

The primary focus of our ontology research (blue boxes in Figure 1) is to develop a set of ontologies that can be used to represent ISO 37120 indicators, their supporting data and domain information. In order for the engine to analyse a city's indicator, it first needs to understand the definition of the indicator. Hence we need to translate the ISO definition from English into a computer understandable representation – this requires an ontology. Second, the engine needs to understand a city's specific indicator value and the data used to derive it. This information may be available in PDF files or spreadsheets but needs to be translated into a computer understandable representation – this too requires an ontology. Third, the engine needs to understand a certain amount of city "common sense" knowledge in order to analyse the data properly. For example, if dealing with primary school student teacher ratio, it needs to understand what grades comprise primary school, the definition of public versus private schools, etc. – this too requires an ontology.

In summary, the objectives are:

1. The development of ontologies for representing the complete definition of each indicator in the ISO 37120 standard.
2. The representation of each city's indicator value (for a particular year), plus the supporting data used to derive it, using the aforementioned ontologies.
3. The development of ontologies for representing theme specific indicator knowledge, such as basic knowledge about education, such as school, teacher, student, grade, etc.
4. The representation of a city's theme specific indicator knowledge. For example, in order to diagnose the education category of indicators, PolisGnosis needs to understand concepts such as what grades comprise Primary school in the city. What schools are defined to be Public schools.

A secondary objective of this work is for the ontology to be used as a standard for the open publishing of indicator information and knowledge by cities on the Semantic Web.

Consistency Research

The second set of inputs to the PolisGnosis Engine is consistency axioms (green boxes in Figure 1). There are a number of types of consistency that need to be checked for in published indicator data. For example, is a city's reported indicator consistent with the ISO

37120 definition? E.g., Is it for public primary schools only? Another type of consistency is whether the information used to derive an indicator internally consistent? E.g., was the data gathered over the same time period.

In summary, the objective is to develop consistency axioms for:

1. Determining whether a city's published indicator data is consistent with the ISO 37120 definition. I.e., is the supporting data of an indicator consistent with its definition.
2. Determining whether city's published indicator data is self-consistent. E.g., are the units of the supporting data consistent, does the supporting data refer to the same geographic area and at the same time.
3. Determining whether the published indicator data for two cities being compared are consistent. E.g., are the units the same. Do they refer to the same time periods.

Diagnosis Research

The third set of inputs to the PolisGnosis Engine it diagnosis axioms (orange boxes in Figure 1). The diagnosis axioms focus on identifying the root causes of differences in indicators over time for a single city (i.e., longitudinal) or how two cities compare at the same time (i.e., transversal). A major issue in diagnosing the root cause of differences is that the data is composed of many types: quantitative, e.g., ratio, statistical, e.g., Population sampling, and logical, e.g., definitions of students, teachers. Sources of change can occur anywhere.

In summary, the objective is to develop axioms for:

1. Detecting quantitative differences, e.g., decrease in doctors due to emigration, patients due to aging.
2. Detecting differences in definitions (description logic and geospatial) of what is being measured, e.g., changes to definitions of students, teachers, doctors. Geospatial changes to city boundaries.
3. Detecting differences due to events that occur, e.g., amalgamation of multiple cities into a single city.

Ontology Architecture

The following diagram (Figure 2) depicts the organization of files used to define the ISO 37120 ontology we are developing. At the highest level, i.e., ISO 37120 Ontology level, http://ontology.eil.utoronto.ca/ISO37120.owl contains the globally unique identifier (IRI) for each ISO 37120 indicator. For example, the IRI for the Student/Teacher Ratio indicator is: "http://ontology.eil.utoronto.ca/ISO37120.owl#6.5".

For each category of indicators in the ISO 37120 specification, for example Education, there is a separate file that provides the definition of each indicator in that category. For example, http://ontology.eil.utoronto.ca/GCI/ISO37120/Education.owl provides a complete OWL definition for all seven of the indicators in the ISO 37120 specification.

The GCI Ontology level provides the category specific ontologies required to define each category's indicators. For example, to define the ISO 37120 Education indicators, we need an educational ontology covering concepts such as schools, teachers, students, cohorts, etc. (Fox, 2014). http://ontology.eil.utoronto.ca/GCI/Education/GCI-Education.owl provides the

classes used by ISO37120/Education.owl. http://ontology.eil.utoronto.ca/GCI/Innovation/GCI-Innovation.owl provides the classes used by ISO37120-Innovation.owl (Forde & Fox, 2015).

All of the category specific indicator ontologies rely about the GCI Foundation ontology[1] for more generic concepts such as population counts and ratios, meta-information, etc. (Fox, 2013a).

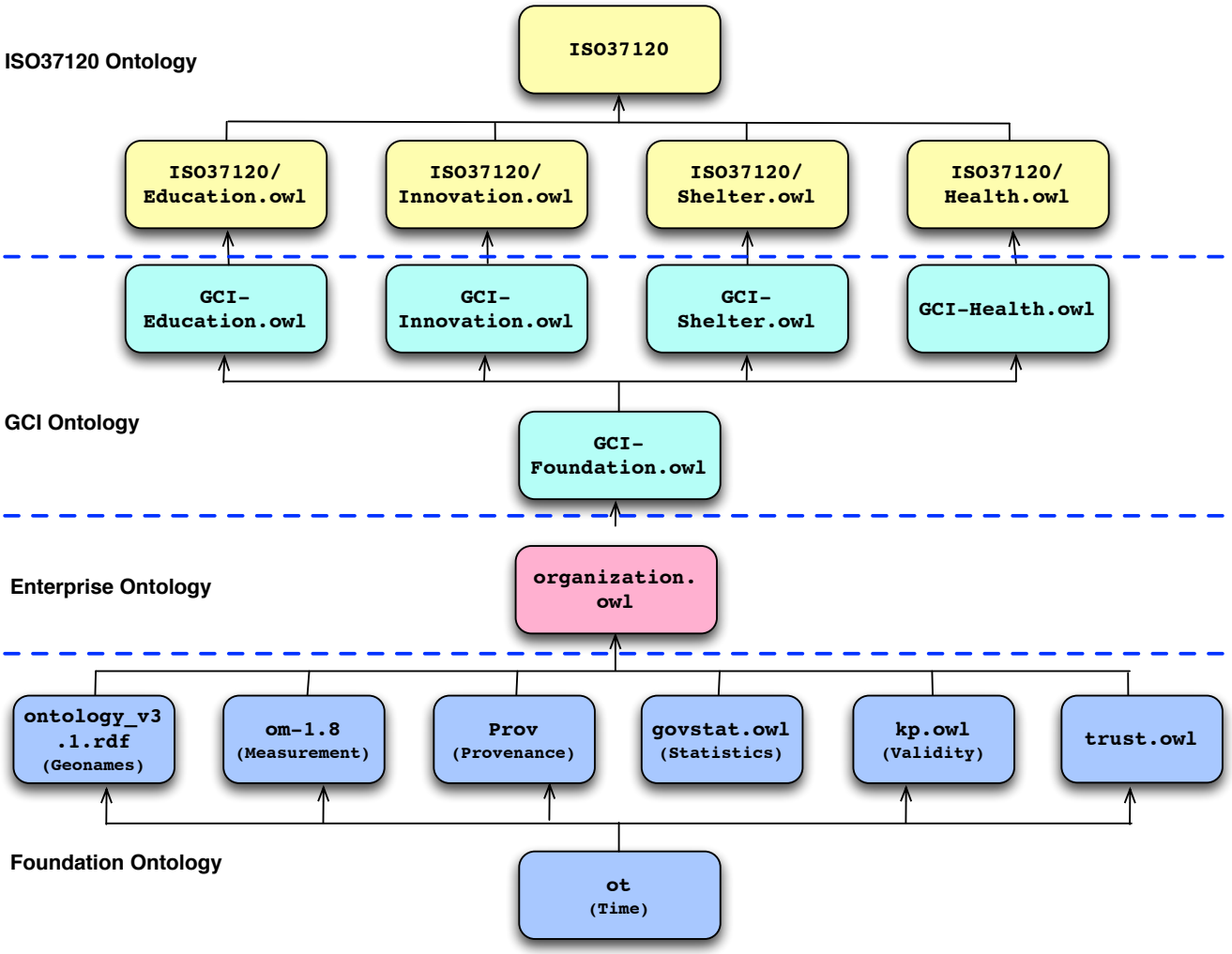

Figure 2: ISO 37120 Ontology Modules

The Enterprise Ontology level contains Enterprise Modelling ontologies. In this figure we only show the Organization Ontology file[2] (Fox et al., 1998), which is one of the TOVE Enterprise Modelling ontologies (Fox & Grüninger, 1998).

Finally, the Foundation Ontology level provides very basic ontologies that were selected as the foundation for the GCI-Foundation.owl ontology.

[1] The GCI Foundation ontology can be found at http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Foundation.owl along with its documentation at http://ontology.eil.utoronto.ca/GCI/Foundation/index.html.
[2] The Organization ontology can be found at http://ontology.eil.utoronto.ca/organization.owl along with its documentation at http://ontology.eil.utoronto.ca/organization.html.

References

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Fox, M.S., and Grüninger, M., (1998), "Enterprise Modelling", *AI Magazine*, AAAI Press, Fall 1998, pp. 109-121.

ISO37120, (2014), “ISO 37120: Sustainable Development of Communities – Indicators for City Services and Quality of Life”, *International Organization for Standardization*, First Edition, 2014-05-15, ISO37120:2014(E).

Appendix: Ontologies

The Global City Indicator Foundation ontology can be found in:
http://ontology.eil.utoronto.ca/GCI/Foundation/GCI-Founation.owl.

The Global City Indicator Education ontology can be found in:
http://ontology.eil.utoronto.ca/GCI/Education/GCI-Education.owl.

The Global City Indicator Innovation ontology can be found in (to appear):
http://ontology.eil.utoronto.ca/GCI/Innovation/GCI-Innovation.owl.

URIs for all of the ISO37120 indicators can be found in:
http://ontology.eil.utoronto.ca/ISO37120.owl.

Definitions of the ISO37120 education indicators, using the GCI Foundation and Education ontologies can be found in:
http://ontology.eil.utoronto.ca/GCI/ISO37120/Education.owl.

Definitions of the ISO37120 innovation indicators, using the GCI Foundation and Innovation ontologies can be found in (to appear):

http://ontology.eil.utoronto.ca/GCI/ISO37120/Innovation.owl.