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# A Requirement List For Geo-ontology Tools

Jochen ALBRECHT

## Abstract

Numerous authors have presented ontology building tools that have all been developed as part of academic projects and that are usually adaptations of more generic tools for geo-spatial applications. While we trust that these tools do their job for the special purpose they have been built for, the GIScience users community is still a long way away from off-the-shelf ontology builders that can be used by GIS project managers.

In our paper, we present a comparative study of ontology building tools described in some twenty peer-reviewed GIScience journal articles. We analyze them from the perspective of two application domains, crime analysis and transportation / land use – both of which are inherently spatial and temporal in nature. For the second example, we developed a database schema, which is sufficiently different from the three main templates for static transportation structures commonly used. For the crime analysis application, we developed a rule base for an agent-based model that had no precursor. In both cases, we were forced to manually code ontologies for use with ESRI-based application software. Based on these experiences, we outline a requirements list of what the tools described in the first part of the paper are missing to make them practical from an applications perspective. The result is an R&D agenda for an important aspect of GIScience.

## 1 Introduction

Ontologies are en vogue. Many conferences such as GIScience or AGILE are dominated by ontology papers and most relevant journals have had special issues on this topic. Even trade magazines have jumped onto the bandwagon, and it is now considered to be good practice to develop domain-specific data models by paying at least lip service to the underlying ontology. “Traditional” (what is traditional in a discipline that was virtually non-existing ten years ago?) ontology building tools such as OilEd, OntoEdit, PowerLoom, Protégé, or WebODE are a) not geared towards geo-spatial phenomena, which by their very nature are also dynamic, and b) are not exactly aimed at end users such as GIS managers in a regional authority. The situation is similar to the fashion industry, where the models on the runway have little to do with Jo or Jane Public. Even the result is the same, in that we are (all made to) feel bad about our inaptitude to develop sound database and service schemas while we are made to believe that this is what we ought to do.

We now have a generation of peer-reviewed articles that describe ontology building tools for geo-spatial applications and the next section will review them to take stock of what may be regarded as the current state of the art. There is, however, an obvious disconnect between these special purpose built tools and off-the-shelf or preferably public domain ontology builders that can be used by GIS project managers. Section Three describes two pro-

jects, where the authors developed complex schemas that on one hand are based on very reasonable needs of the practice, while on the other hand completely beyond the scope of what could be produced by currently existing tools. This suggests a gap in current applied research and we therefore conclude our paper with a list of recommendations on how to address this mismatch.

## 2 State of the Art – in Theory

General purpose ontology builders and editors have matured, at least from an information scientist's perspective (Duineveld *et al.* 2000, Cardoso & Escorcio 2007). Within academia and in the open source world, Protégé (2007) has become the tool of choice for close to 100,000 registered users, who (in addition to it being free) appreciate its many extensions for different paradigms (frames vs. OWL), multiple APIs, many export formats, and several different editing tools. Originally developed for the medical community, it is now widely used, even in geo-spatial communities (Souza *et al.* 2006, Lüscher *et al.* 2007). However, Protégé has its limitations. As Lüscher *et al.* (2007, p. 9) point out, "Protégé may be too complex for domain experts". They therefore employed a special user interface for creating spatial patterns. Another issue is that while Protégé is well suited for the development of Semantic Web applications, most GIS are still desktop- or heavy server-based, i.e., they require a database schema. Protégé can read database schemas but cannot export to them (database schema may however be created through a JDBC plug-in).

The solution to this is therefore to move to another public domain ontology editor called WebODE (2003). As the name suggests, WebODE is the web-based front-end to what the authors call an Ontology Development Environment (ODE). In its latest incarnation as ODE Semantic Web Services designer (Gómez Pérez *et al.* 2004), this tool limits itself to the creation of OWL-S services, albeit in a very comfortable manner. Of higher value for our purposes here is the still available version of WebODE 2.0, which exports to wide range of data exchange standards such as XML, RDF, OWL, Java/Jess, and UML. The latter two can be used to then create database schemas in, for example, Oracle or MySQL (Corcho *et al.* 2002). This gets us a long way towards linking original geo-spatial ontology development with the creation of professional GIS database schemata. However, a GIS is more than just a data repository.

As Noy & Guinness (2001) point out, programmers make design decisions based on the operational properties of a class such as methods or procedures, whereas an ontology designer makes these decisions based on the structural properties of a class (type and interface definitions). In consequence, we are still short of ontologies of geographic processes, and ontologies are much easier translated into a database schema than into process models.

Both Protégé and WebODE allow for OWL-S output, i.e., the specification of services, which according to the WorldWideWeb Consortium (W3C 2004) can in turn be modeled as processes. We have, however, yet to see the development of geographic process libraries, notwithstanding the efforts of NASA (Raskin 2004), a few intrepid companies (GOL 2004), and the odd GIScientist (Reitsma & Albrecht 2005, Peachavanish & Karimi 2007), the formal specification of geographic processes is at this point restricted to web services and queries á la Google Maps. This should come as no surprise because the ontology community has not really gone beyond the SNAP/SPAN view introduced by (Grenon & Smith

2003). We are still missing a practical ontology of process that is both proven to be formally correct and at the same time well enough developed to reach to the level of real world applications.

The best we have at this point is UML output based on OWL-S encoded ontologies. As mentioned above, (web) services, the usual target of OWL-S ontologies are a far cry from the complexities of desktop-based spatial decision support systems. The best link that these authors have found so far, is a commercial ontology editor called SemTalk (2008). Originally designed for business workflows, it is an OWL interpreter developed as an extension to MS Visio. Formal consistency is assured with the open source OWL reasoner PELLET (2008). Pre-existing ontologies such as SWEET (Raskin 2004) can be imported and form the foundation for subsequent user-defined extensions. One of the advantages of this tool is its relationship with MS Visio, a wide-spread software package that is also commonly used to define the data models for various ESRI communities (ESRI 2008). This allows for using one and the same tool to define both geo-spatial data structures and processes.

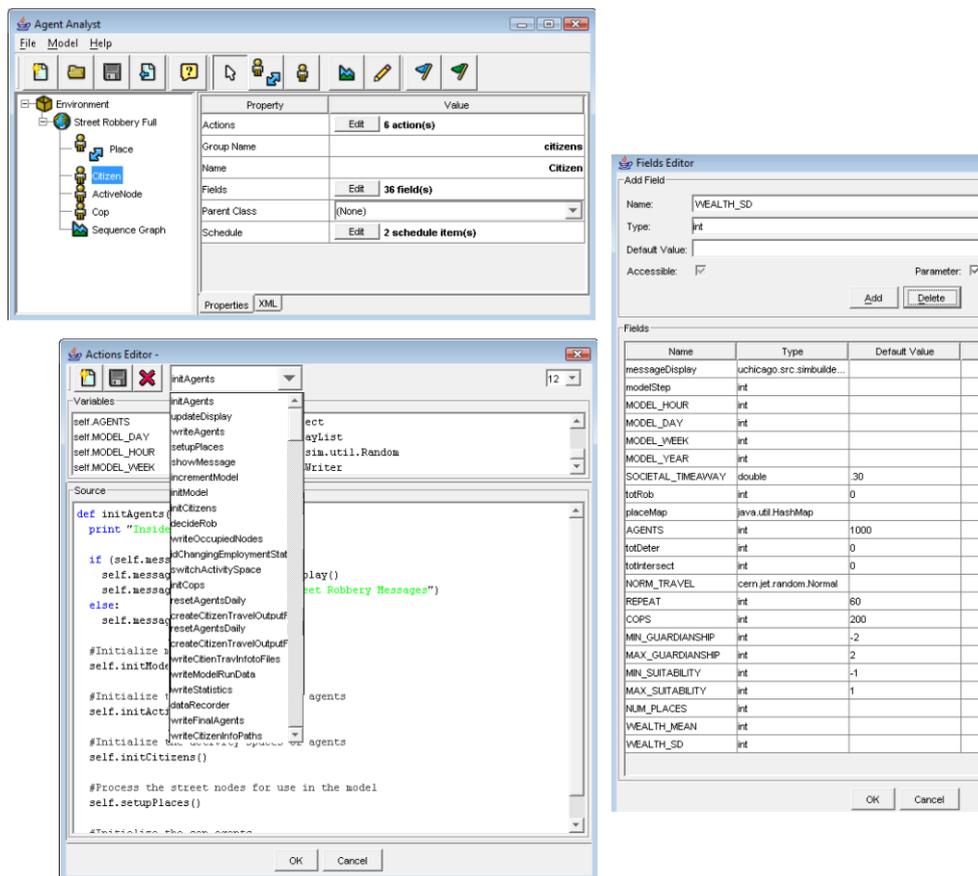
In the next section, we will discuss two larger application examples, where the authors struggled with the definition of new data and process models. This discussion is intended to illustrate the needs from an applied perspective, in this case two university / public agency partnerships.

### **3 Practical Experiences Highlighting Gaps between Theory and Practice**

This section consists of two parts. In the first, we describe and analyze the needs of an agent-based GIS model developed by Groff and described across a range of publications (Groff 2007a, b; 2008). The emphasis in this discussion is on the formal specification of agent behavior in a geographic context. In the second part, we look at a transportation / land use model developed for a regional planning authority. In both cases, the authors are forced to manually code their ontologies rather than using any of the above mentioned tools.

#### **3.1 Formal specification of actions in an agent-based GIS**

This model has been described in detail in Groff (2007a, b). We will here instead focus on the process of agent specification, which is documented in form of a sample application of AgentAnalyst (2008). The agent-based component is a Repast (North *et al.* 2006) application that links to ArcGIS using a Python interface. Following the logic of Kuhn (2001) Groff develops a formal framework of agent actions within a well-defined context, in this case crime analysis. Theodorakis *et al.* (1999) and subsequently Cai (2007) describe such a process in abstract terms but show no attempt of an implementation. Groff (2008) develops her specifications the way a programmer would: defining in a painstaking iterative process all the variables and actions of the agent based model (**Fig 1**) and arranging them in the complex schedule that operates at four different hierarchical levels.

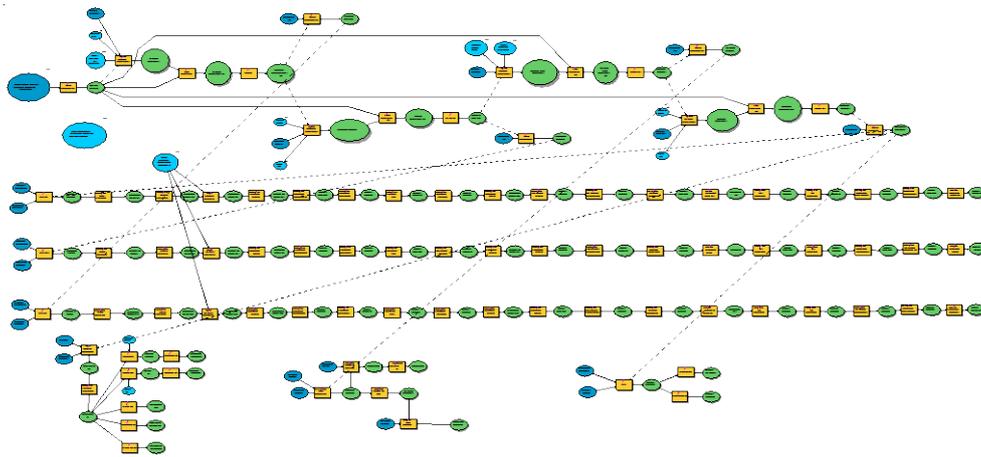


**Fig. 1:** Top-level view of the variables and activities of a street robbery model. The Edit buttons in the top left window open the respective Actions and Fields (variable) editor windows displayed on the bottom and right. The Actions Editor in turn creates the stubs for Java classes and methods.

The total model consists of four types of agents (places, citizens, cops, and activity nodes) that perform 35 defined activities based on the state of 64 variables. It took Groff a good year of her PhD to develop this model. There are no tools that assist in the setup of the model logic, or that would help with the checking for formal consistency of the model. In an agent-based model, the agents are supposed to act depending on context. From a developer's perspective, this context, however, gets fast out of hand because of the combinatorial explosion of possible situations among the many dimensions that Groff's model spans. Ali *et al.* (2007) address this problem with a spatial variant of an online analytical process (OLAP) to keep track of the complexities in the real-time analysis of their multi-agent geosimulation software decision making process. This takes care of some of the implementation issues but leaves the question of ontology-based design tools that this article is about unresolved.

### 3.2 Formal specification of a land use-based transportation model

The second model to be discussed here has not yet been released to the general public and the description is purposefully general as to not identify the agencies involved. Goal of this spatial decision support system (SDSS) is to model existing flow in a multi-modal network and to find optimal locations for transit hub based on existing parcel-level land use. The resulting geodatabase (all vector data) is approximately 2 GBytes in size, and the procedures of the SDSS combine many hundred GIS operations for a single model iteration. A superficial view of the geoprocessing model is depicted in **Fig 2**, while **Fig 3** provides a top view of the underlying database schema.



**Fig. 2:** Top-level view of a land use-based transportation hub siting model.

GIS databases are often treated as mere repositories that once created are frozen in time and form a stable basis for subsequent analysis. The efforts of creating a database are hence neglected in academic literature (notwithstanding publications on management (Huxhold & Levinsohn 1994, Tomlinson 2003, Watson 2005, Obermeyer & Pinto 2007, Yeung & Hall 2007), metadata (Williamson *et al.* 2003, Nogueras-Iso *et al.* 2005, Wootton 2007) or spatial decision support (Geertman & Stillwell 2002)).

Similar to the crime model of the previous section although not at the fine-grained individual level of perpetrators and victims, our very model structure is dynamically changing as we run the model. For instance, the choice of a commuter's mode or route is influenced by how many other commuters crowd one's first or second option. Many train riders in Seattle, for example, are familiar with the added number of passengers when flooding closed a highway during exceptional rainstorm in fall of 2007. The same happens on a smaller but cumulatively as effective scale every day in metropolitan areas around the world. From an abstract perspective, the phenomenon is well studied and has become a popular example in complexity theory (Qiu *et al.* 2000, Sheng *et al.* 2005; Selçuk 2007). As a matter of fact, it is one of the hallmarks of complexity theory (Gimblett 2002) that its object arises from innocent looking simple setups. With the exception of a draft paper by Line (2004), there is



## 4 Conclusions, aka a Call for a Research Agenda

Based on the above examples we outline a requirements list of what the tools described in the first part of the paper are missing to make them practical from an applications perspective. Klien & Probst (2005), as well as daSilva *et al.* (2005) call for research on methods and tools that support application ontology engineering, e.g., by automating the process of creating application ontologies. We cannot agree more. So, how do we get there? Apparently, the problem is non-trivial; the authors are not aware of any solutions in the wider non-spatial realm.

In a first step, we need to increase our efforts on the low-level ontology side. Grenon & Smith's SNAP/SPAN dichotomy is a neat logical device to compartmentalize views of dynamic phenomena but we need a unified view that allows for the application of one methodology rather than the continued parallel use of two. Reitsma (2005) introduces a radical approach, which does not seem to have found too big a following, yet she seems to have been onto something: Line (2004) and Raskin (2004) independently came up with similar notions of 'flux' and 'trajectory' that do away with the idea that we can capture processes in form of discrete automata steps. In information science, the solution to the latter was introduced by Petri (1962). Petri nets, also known as place / transition nets allow for formally complete specifications, are uniquely suited for dynamic phenomena, and could conceivably be linked with network- as well as with Voronoi-based GIS (e.g. Gold since 1987). The International Standards Organization (ISO/IEC JTC1 2005) is about to accept a Petri Net markup language that will go a long way towards public access to what used to be a rather theoretical tool.

Second, we need spatio-temporal schema editors that assist with the development of complex scheduling and update routines in dynamic models. Even industrial-strength UML tools like Rational Rose (2003) cannot cope with the spatio-temporal granularity of models such as those described in the previous section. SemTalk (2008), described in section 2, comes closest so far, but is constrained by the limitations of OWL-S. An immediate solution for this problem is not visible, as this kind of optimization of a geo-spatial process model specification is not an inherently academic endeavor. Similar to the development of true three-dimensional GIS, we may even miss the inauguration of such tools because they remain behind the closed doors of the defense and oil industry.

Third, and with kudos to an anonymous reviewer, we need to revisit the ontologies of fields discussion of 1998 (Kemp & Vckovsky) and 1999 (Peuquet et al), which lead to wonderful philosophical insights but was never picked up by the tool building community.

Finally, and here we join the tenor of Klien & Probst (2005), a wide-spread move from static GIS repositories to GIS-based process modeling systems requires the development of reusable libraries of process model specifications, similar to their counterpart in the data model world. This is of course dependent on the availability of standardized tools and methodologies – the steps one and two from above. Until then, the conceptual difficulties of bridging domain-specific models (Albrecht 2007) as well as the sheer effort required to develop real-world dynamic GIS will render them a rare and endangered species.

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