From Workflows to Action-Driven Ontologies: Towards a Framework for Interoperability of Geographical Processes

GILBERTO CÂMARA[1], MARCELO TÍLIO MONTEIRO DE CARVALHO[2], FREDERICO FONSECA[3], MARCO ANTÔNIO CASANOVA[2], JOÃO PAIVA[1], FERNANDO GIBOTTI[1]

[1]Image Processing Division, National Institute for Space Research (INPE), P.O.Box 515, 12201-001 São José dos Campos, Brazil

[2]TECGRAF/PUC-RIO, Catholic University of Rio de Janeiro, Av Marques de São Vicente 1758, Rio de Janeiro, Brazil

[3] School of Information Sciences and Technology, Pennsylvania State University University Park, PA 16802, USA

Extended Abstract

1. Introduction

The concept of "action-driven ontologies" has been proposed by Câmara et al (2000) to refer to knowledge discovery and representation schemas which aim at capturing the user intentions and the dynamics involved in the computer representation of geographical data. This concept is based on a definition of space as "a system of objects and a system of actions" (Santos 1996) and is an extension of the idea of Ontology-Driven Geographic Information Systems (Fonseca and Egenhofer 1999). In *action-driven ontologies*, the emphasis is placed on the *dynamical* character of geographical entities and the *intentionality* dimension of geographical space. The dynamical perspective is stressed by the fact that, in real life, geographical entities are continuously being transformed and new ones are being created. Even more relevant to GIS-based ontology research is the semantic impact of the user's intentions, in situations such as: *"How do we choose the classes of a suitability map?" "Why do we represent a soils map in a certain fashion?" "Why have we used a certain set of land use classes to interpret a remote sensing image?"*.

Moving from a generic concept towards a useful practical context requires a formal definition of the concept of action-driven ontologies. In this work, we present such an approach, whose goal is to propose a formal representation of *workflows* in an ontological context. Workflows are a popular way of representing processes and flows

of control in spatial decision making processes, and consist of a sequence of transformations applied to a data set (Carvalho et al., 2001). However, there is a major barrier for achieving interoperability of such procedures. "How can two workflows applied to the same data set be considered to be equivalent?" To achieve such interoperability, we introduce the concept of *ontological morphisms*, that are based on the application of notions of category theory to the problem of spatial ontologies.

2. Ontological Morphisms: Category Theory Applied to Spatial Ontologies

Category theory is the algebra of functions; the principal operation on functions is taken to be composition (Walters 1991). The application of category theory to GIS has first been discussed in Herring et al (1990), which propose its use for abstract modeling of geographical operations. This concept has been extended by Frank (1999), which indicates how abstract algebras can be use for a generic definition of geographical operations. In our proposal, we will use category theory as a source of inspiration rather than as an objective in itself. We shall use the conventional programmer's jargon and intuition, but take care not to exceed the spirit of category theory.

The key to our proposal is treating ontologies as *generalized types*: name ontologies (equivalent to nouns) that can be defined as static types and action ontologies (equivalent to verbs) consist of functions on generic types. This corresponds to the definition of a category, which consists of a set of objects and a set of functions. This proposal achieves a clear separation between the dynamic actions and the static descriptions of geographical data. A key concept is an *ontological morphism* (see Figure 1), inspired by the *natural transformations* of category theory (Walters 1991), which indicates a situation where two results have been obtained by applying two sets of spatial transformations on two sets of ontologies. For the results to be comparable in a practical sense, the two sets of initial ontologies must be equivalent, in the sense that a transformation between the two sets is possible. Additionally, the two sets of spatial transformations must also be equivalent, in the same sense. Producing equivalent results is paramount to achieving *interoperability* between two spatial decision-making procedures.

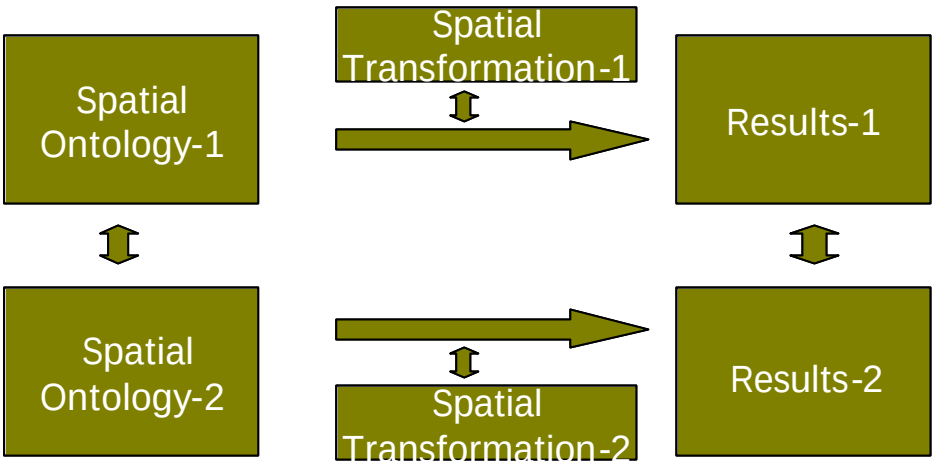

Figure 1 – An Ontological Morphism

3. A Case Study in Action-Driven Ontologies

We propose to apply our concepts to a real case-study, an automated system designed to improve the response to emergency situations. The system includes agent-based approaches and spatio-temporal information, easy access to vital information and tight control over the resources allocated to face an emergency. The system is currently in development to be used at PETROBRAS (Brazilian oil company) and its subsidiaries, incorporating the company's technical experience. The system is applicable to pipelines, oils terminals, oil refineries and offshore installations, and it also proved to be a valuable training tool. The system works with *local emergency action plans*, which are structured collections of actions, coupled with information stored in geographical as well as conventional databases. During an emergency, the team follows a previously stored plan, backed up by its ancillary information. The team registers the actions taken and documents eventual difficulties. Later on, upper level management may use the system to generate reports that are useful to detect eventual problems with the plan or to assess the performance of the team. In our case study, we have formalised the action plans as generic procedures, which can be compared to indicate that the can produce equivalent results.

4. Conclusions

The authors propose a framework for using ontologies to improve interoperability of spatial decision-making procedures, which is applied to a case study on decision making for emergency action plans. The proposed approach represents a possible way for using the idea of *action-driven ontologies* in a useful context.

References

Câmara, G. M., A.M.V.; Paiva, J.A.C; Souza, R.C.M. (2000). *Action-Driven Ontologies of the Geographical Space*. In:M. Egenhofer (ed),GIScience 2000, Savanah, GA, AAG. <http://www.giscience.org>.

Carvalho, M.T., J. Freire, M.A. Casanova, "*The Architecture of an Emergency Plan Deployment System"*, III Workshop Brasileiro de GeoInformática, Instituto Militar de Engenharia, Rio de Janeiro, Brasil (Oct. 2001).

Fonseca, Frederico, and Max Egenhofer. 1999. Ontology-Driven Geographic Information Systems. Paper read at 7th ACM Symposium on Advances in Geographic Information Systems, at Kansas City, MO.C. Bauzer-Medeiros (ed), ACM Press, N.Y., 1999.

Frank, Andrew. 1999. One Step up the Abstraction Ladder: Combining Algebras - From Functional Pieces to a Whole. Paper read at COSIT'99.C. Freksa and D. Mark (ed), Lecture Notes in Computer Science 1661. Springer-Verlag, 1999.

Herring, J., M. Egenhofer, and A. Frank. 1990. Using Category Theory to Model GIS Applications. In *Fourth International Symposium on Spatial Data Handling*, edited by K. Brassel and H. Kishimoto. Zurich, Switzerland.

Santos, Milton. 1996. *A Natureza do Espaço (The Nature of Space)*. São Paulo: Hucitec.

Walters, R.F.C. 1991. *Categories and Computer Science*. Cambridge: Cambridge University Press.