Bottom-Up Development of Process-based Ontologies

Taciana LemosDias, Gilberto Câmara
Image Processing Division - Brazilian National Institute for Space Research
São José dos Campos, SP, Brazil
{taciana, gilberto}@dpi.inpe.br

Frederico Fonseca
School of Information Sciences and Technology - The Pennsylvania State University
State College, PA, USA
ffonseca@ist.psu.edu

Clodoveu Davis
Minas Gerais Catholic University and PRODABEL
Belo Horizonte, MG, Brazil
clodoveu.davis@terra.com.br

Introduction

The development of information systems is based on a set of concepts, defined in accordance to the reality and context of the system's intended application domain. Considering the existence of this application domain, ontology-driven information systems [2] use descriptions of the mental models of a community for a given share of the reality as a tool to express the semantics that must be adopted in the applications. This allows the sharing and reuse of this knowledge in other application development processes.

Spatio-temporal information systems, in particular, benefit from the ontology-based view. These information systems usually operate mostly with identifiable objects that include spatial, non-spatial, and temporal characteristics [1, 4, 8]. Ontologies can be used to determine under which conditions these objects acquire or lose their identity, how their properties change over time, and how they can be divided into other objects [3]. Thus, the ontology must relate both to the semantics of the objects and to the semantics of the processes that generate changes in the real world.

This paper proposes the definition of a set of operations that are essential as a semantic base for the definition of ontologies. These operations are based on processes that model the life and evolution of spatio-temporal objects, as represented in an information system. Such operations are based on the spatial characteristics of the objects, on their descriptive attributes, and on the definition of their identity. Our objective is to model complex transformation processes that take place over time, using these operations as fundamental building blocks. Thus, we focus on vector-based spatial representations and on discrete linear-time intervals [10, 13, 15].

Process-based Ontology

Process-based ontology is used to represent changes in objects over time, according to recent studies on the correspondence between the object-oriented and the event-oriented views of the world [3, 9, 14]. Using process-based ontology, it is possible to store, manage, and retrieve the processes that have determined, through time, the changes that took place at a given location, along with the history of each spatial object. An information system that is built observing this paradigm would be able to count on not the latest version of each relevant object, but on the process that led to the present situation.

A process-based ontology includes the semantics of the objects and processes. It allows the materialization of the history of objects using more than just a chain of object versions over time, since the processes by which changes take place are also stored. Processes describe, along with the objects involved, details on the constraints, conditions, and operations that set off object evolution. Processes can also change through time, therefore following process versions is also needed.

We propose the modeling of processes using a bottom-up strategy, in which processes are composed with *events*, which in turn are composed with *operations*. In this strategy, a process is a broader concept that considers all aspects of the change, including semantic details, such as constraints and rules that are specific to the desired representation of the universe of discourse. Processes are defined through the composition of *events*, each of which belongs to a predetermined set of possibilities. Events can be seen as steps from which processes are formed; therefore, their definition is semantically more general. Using events, steps in the development of a process can be specified in an adequate temporal order, so that changes in the state of objects can be recorded. In turn, *operations* are used to define events from an even simpler set of generic actions. These operations include generic identity-based changes [1, 5, 6, 7, 11, 12], modifications on the geometric shape, or on the contents of descriptive attributes. Moving from operations towards processes, semantic details must be added, thus making the definitions progressively more specific in terms of the information system (Figure 1).

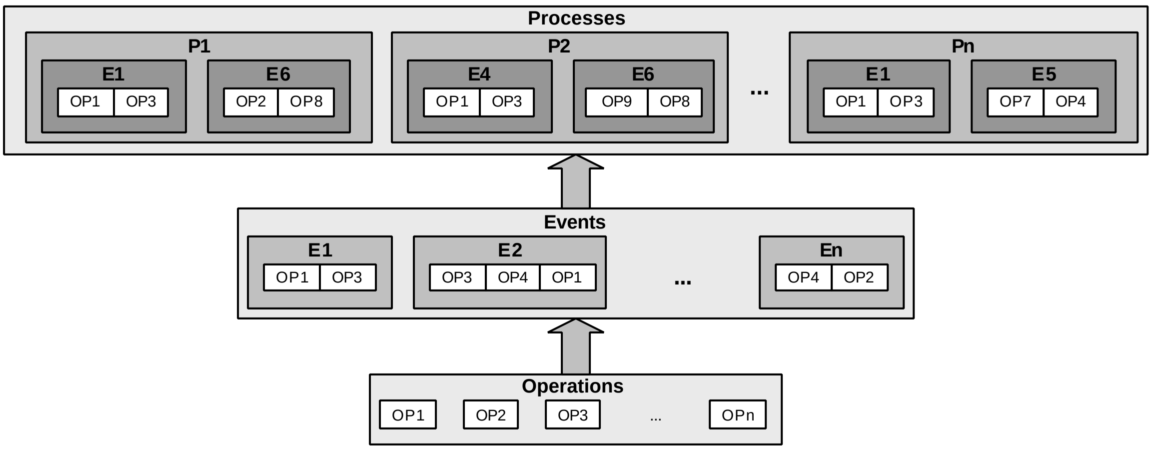

Figure 1 - Process-based ontology levels

Even though objects evolve, within a given knowledge domain, according to process rules that are ontologically connected to their definition, these rules ultimately have an effect on elements of the objects' representation, such as their geometric shape, descriptive attributes, and identity. We argue that complex processes can be specified from a kernel of simple operations on those representational aspects. This can be achieved through a computational environment that enables specialists to arrange and combine operations into events and processes, adding rules wherever it is necessary, according to their view of the reality.

An example of the bottom-up strategy is the process of opening a new street. The space to be used by this new street (Figure 2) runs through some previously existing parcels (such as A), thus requiring the reacquisition, by the local government, of parts of these parcels, and the merging of these parts to become part of the city's street network. Figure 2a shows the initial situation, in which the area required for the new street is defined. Next, the section of parcel A to be transformed is obtained by geometric intersection (Figure 2b). The remainder of A is then obtained through the division of the former area into two objects, one of which retains the identity of A, and another (A1) with the same characteristics of A (Figure 2c). Finally, A1 and all other parts of parcels that compose the area of the street are joined together and transformed into public property, thus evolving into a new object, S (Figure 2d). In this example, we would use at least four operations: `IntersectGeom`, `DifferenceGeom`, `CreateObj`, and `DestroyObj`. We would also need additional operations to deal with attributes. These operations would be used to define two events: `DivideObj` and `EvolveObj`. The process will then use `DivideObj` and `EvolveObj`, along with additional rules that are specific to the case of land parceling.

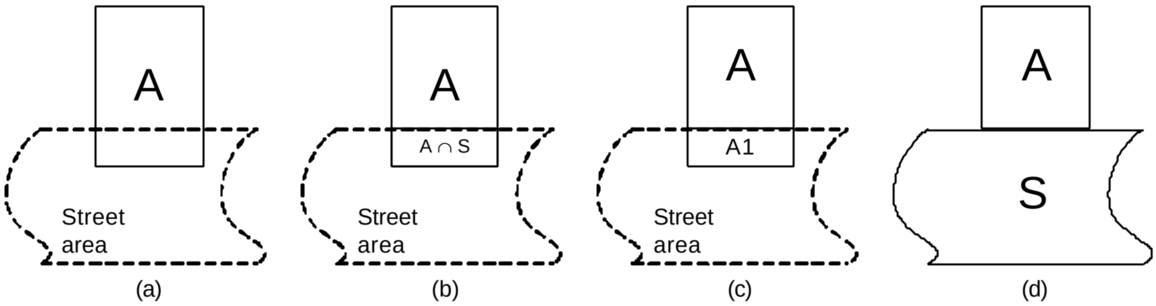

Figure 2 - Reparcelling process

Notice that events, such as `DivideObj` and `EvolveObj`, can be developed using much more than simple geometric operations. Additional operations, by means of which a historic account of the transformation of each object can be maintained, can also be incorporated in the design of the events. With this, land parceling processes can be defined in a high level, using previously defined events, which encapsulate complex transformations and object history recording.

Conclusions and Future Work

We observe that the representation of the life and evolution of geographic objects seems to be semantically richer when change-generating processes are used to describe their history. A process-based ontology can facilitate the development of information systems that are closer to reality, since they are based on process rules that derive from a pre-established set of events and operations. This approach also facilitates the adaptation of processes to various local contexts, not only by maintaining the semantic definition of a process, but implementing it according to a different set of events that are significant in a given context, such as local laws and standards.

This work is in progress. Its results will include an ontology that will be validated and verified through the modeling of evolution processes over a case study, to be developed over a cadastral information system. In that situation, land parceling processes, which are bound by complex legal and administrative constraints, have effects on the identity, geometric shape, and attributes of objects such as land parcels over time.

This proposal will be formalized and validated using the Haskell functional programming language [3, 9], which enables the verification of the operations and the detection of semantic errors in a clearer and more succinct manner.

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