GeoComputation: A Coordination-Oriented Approach

Junyan Luo and Mark Gahegan

Department of Geography
Pennsylvania State University
State College, PA 16802, USA
Tel: +1-814-8659656
Email: jyluo@psu.edu

Biography

Junyan Luo is a Ph.D student from the Department of Geography, Pennsylvania State University. His interests include GeoComputation, knowledge representation, geospatial software integration, and the applications of intelligent agent systems.

Introduction

During the past several years the research under the banner of "GeoComputation" has been developed in an open and diverse manner, with a wide range of techniques and application domains been addressed from various perspectives. While plurality and inclusiveness have been regarded as the strength of GeoComputation (Gahegan 2000), however, the diversity of expertise (which is usually very specialized) required to understand the proposed tools and the heterogeneity introduced by different tool providers have became major barriers to the successful application of GeoComputation in real world problem solving, especially when the targeting problem requires various tools and techniques to integrate and work as an analytical whole. This raises interesting interoperability issues that are not just about the sharing of data, but also related to the integration of problem solving knowledge in a much broader sense, including how to make methods accessible to domain users who are not technical experts, how to share functionalities between different tools, and how to capture and maintain consistency when knowledge are transferred between systems and subjects.

This paper initiates an attempt to establish a methodological foundation for the sharing and integration of problem solving knowledge in the GeoComputation contexts. The central idea of our approach is the concept of "coordination", which is used to denote the general mechanism for different problem-solving resources to integrate consistently and work harmoniously towards the desired goals (here "resources" include all the information, expertise, and tools available in the given problem-solving context). The concept of coordination has been intensively studied in many areas, including organization theory, sociology, and computer science. Although there are many varieties and debates in the studies on coordination, the following are some points that have reached wide agreement:

- Coordination is about ***communication and interaction***. Coordination is concerned with not only the low level exchange of data, but also high-level communication of knowledge. Furthermore, the process of interaction is critical to coordination.
- Coordination is ***action*** oriented. The purpose of coordination is to organize different activities to achieve given tasks.
- Coordination can be viewed as ***meta-information*** sharing and processing. Essentially coordination is the additional information processing work that is indispensable when multiple information sources and processing units are involved during a course of problem-solving work (Malone and Crowston 1994).

The concept of coordination has rich implications for geosciences in general and GeoComputation in particular. Most geospatial problems are multidisciplinary in nature and require knowledge, information, expertise, and methods from different domains. Coordination defines the ***protocols*** of communication and cooperation during the problem-solving processes, and provides guidelines for designing the proper ***metadata*** structure that support high-level knowledge sharing. The goal of the proposed coordination framework in this paper is to create a knowledge sharing and integration structure for geospatial problem solving, which supports the management of various problem-solving knowledge, enables the integration of different tools, and eases the uses of GeoComputational techniques for domain users.

Current Development

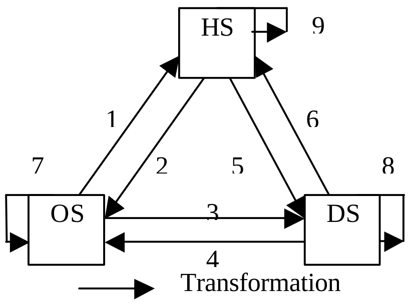
Briefly speaking, the proposed coordination framework is composed of three layers: the conceptual layer, the representational layer, and the application layer.

1. The Conceptual Layer

Recently researchers have identified the importance of building conceptual models about geo-space-time for GeoComputation (Couclelis 1998). However, given the multidisciplinary nature of the targeting domains, it is unrealistic (or impossible) for GeoComputation to develop a conceptual model that satisfies the needs of all problems. Consequently, the coordination approach presented in this paper does not try to directly define a conceptualization of space-time. Instead we attempt to establish the conceptual foundation at the **meta-level**, and develop an abstract model of coordination based on the **transformation** between conceptual models (Gahegan 1996).

The transformation of knowledge is defined as a set of **actions** between different conceptual models about space-time called **nodes**. Each node plays one of the following three kinds of knowledge roles (Figure 1): the hypothesis space (HS), which refers to the information processing subject's view of the world (e.g. the researcher's world view and the analytical tool's built-in assumptions); the data space (DS), which defines the structure of information storage (e.g. the database schema), and the observation space (OS), which denotes the space from which data is captured (e.g. the physical world, paper maps, and pictures on the screen). One should note that the knowledge transformation path is different from data flow: the latter usually represents the transfer of information, and the former describes the transformation of semantics.

The major benefit of the proposed conceptual model is that by explicitly conceptualizing actions, it captures the knowledge production and transformation processes. A node plays knowledge roles rather than uses concrete conceptual models, which relaxes most constraints on the underlying conceptualization while retaining useful information for knowledge sharing. For example, we could represent knowledge transformation in a land use / land cover classification application as the diagram in Figure 2, no matter what data structures and classification methods the problem solvers use. It is also possible to design automated tools that searches through the node to construct a work path.



1. observing
2. concept presenting
3. data capturing
4. data presenting
5. data modeling
6. data interpreting
7. physical transformation
8. data transformation
9. concept interpreting

Figure 1. Transformations between cognitive, observational, and representational space

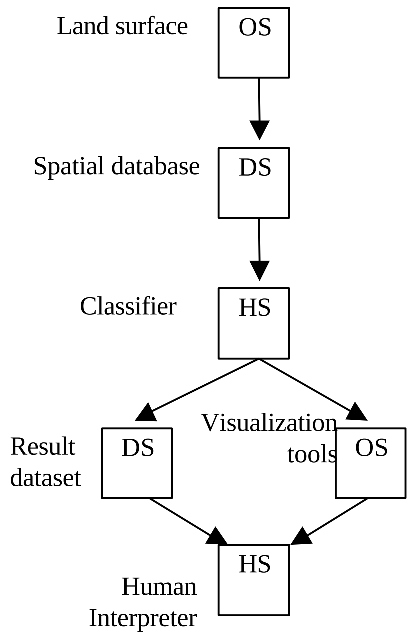


Figure 2. Knowledge transformations in land use / land cover classification

2. The Representational Layer

The representational layer formally realizes the conceptual layer using knowledge representation languages. Currently we are proposing a reference representation layer built upon the DAML (DARPA Agent Markup Language) knowledge representation language (DARPA 2001). The core classes in the reference representation include:

- Action; which is represented as a function that transform a set of initial states into a set of resulting states;
- Info; which represents the DS role in the conceptual layer;
- Presentation; which represents the OS role in the conceptual layer;

- Concept; which represents the HS role in the conceptual layer.

Additional classes can be created through subclassing the above core concepts.

3. The Application Layer

The application layer addresses the various application scenarios in geoscientific and GeoComputation contexts. Conceptually the proposed framework should be able to represent all application cases in geospatial domains. The application cases this paper will discuss include:

- Knowledge management and sharing. It is concerned with how to use the proposed coordination framework to store, manage, and query information, models, and even solutions in a consistent and semantically meaningful manner.
- Automatic software solution construction. Since resources, including information sources and processing tools are explicitly represented, it is possible to query and compose high-level solutions automatically according to users' needs.

Outline Of The Paper

The proposed paper has seven sections. After the introduction in the first section, the basic ideas of coordination and its implications to GeoComputation are discussed in section two. Section three to five describe the three components of the proposed coordination framework as mentioned above. Section six presents a use case from the land user / land cover classification domain. A high level JavaBean™ component management and query system is described, which uses the coordination framework to construct and maintain a component repository for the geo-visualization and analysis tools developed in the GeoVISTA Center. Users can query the component tools according their high-level problem-solving needs, and a software assistant is provided to aid problem solvers to compose the java components into a classification solution in a semi-automatic manner. Finally, a conclusion is presented in section seven.

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