Analyzing Spatial –Temporal Geographic Information based on Blackboard Architecture and Multi-Agent System

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Summary
In a lot of theoretical and practical applications of different geographical disciplines, the use of Geographical Information Systems (GIS) is by now a more or less common issue. Visualization, presentation, administration and analysis of geographical relevant data are a main feature of scientific research and teaching. Furthermore, in commercial contexts like advertisement, marketing, navigation, administration, project management and planning becomes crucial. The retrieval and location of geographic information will require a significant amount of time and effort. In addition, different users usually have different views and interests in the same information. In order to resolve such problems, this paper proposes a generic geographic information model system based on blackboard architecture and multi-Agent (MA) architecture. By paralyzing tasks and offering more efficiency and flexibility, this approach seems to be fruitful in order to construct flexible and extensible system improving more capability and efficiency of GIS services. We further illustrate the design and implementation of the multi-agent system that uses image analysis agents for generating and processing parallel programs by calling the available method. In a first time, we validated our approach on satellite images of SPOT4 representing a north Tunisian region for different dates in order to detect changes for a possible prediction and a better decision making and in a second time we represent how to model and represent geographic data.

Key words:
Geographic information, temporal information, multi-agent system, changes detection.

1. Introduction

Over the past, GISs have been widely adopted in support of planning, agriculture, forestry, infrastructure maintenance and many other fields. Geographical information includes maps, images, data sets, analysis operations and reports. Nowadays, this tool contains a huge source of geographical information and offers already many different services. The advantages of using such technology are obvious to most users of geodata and geoprocessing resources. However, effective use of information is becoming increasingly difficult because of their sheer size and diversity, thus intelligent GIS needs to be developed. In contrast to this the use of tools provided by Artificial Intelligence is marginal in spatial analysis. Moreover the developing of GIS technology has made it available to a growing number of people form different disciplines and different backgrounds. However the degree of productivity they can achieve is limited by their lack of technical knowledge about GIS tools, which are becoming large packages with more functionality [1].

Several works concerning the interpretation of different types of scenes using the knowledge based approach and GIS have been successful. Among these works, we can cite the Sigma, Kids, Icare systems which based on an expert system, the Aerosol and Alain Boucher’s system which based on multi-agent system [2], the Vision, MessieI and Skids system which based on blackboard architecture [3].

Unfortunately, none of them propose a generic architecture for a scene analysis system which can be application independent. In fact, the knowledge representation and the reasoning strategies in most of these systems are often application. This is a big drawback because that means new development have to be made for each new application. But on the other hand, an important, fact emerges: the use of blackboard architecture, in most of these systems, to design scene analysis applications. This architecture seems very adapted to model a high level vision process. Its main characteristics are: a global data base which can be organized in different levels of representation, a highly modular structure and an easy management of various strategies and reasoning control.

Application of intelligent agents in the GIS environment is actively being explored and some projects have been reported where different types of agents are being employed to improve usability of GIS software as well as users access to geospatial data and services. Geospatial information retrieval and filter, intelligent geaospatial search, knowledge discovery, decision model and

Manuscript received July 20, 2006.
Manuscript revised August 24, 2006.

assessment are typical applications based on using agents in GIS [4].

2. Agent technology

Geographic Information includes digital, literal, graphic and image information which directly or indirectly relates to various quantity, quality, distribution features, spatial relation and rule in the geographical field [5]. GI has three basic functions of describing, recording the spatial location and reflecting the transformation process of the phenomenon, and is basically the relating of all kinds of information in the real world and forming a synthesis information entity that is continually distributed in time and space.

The concept of Agent originated from Distributed Artificial Intelligent (DAI) [6], and is a basic term of DAI. In the context of spatial reasoning, the term agent is mostly used to describe a system that performs a specific task as route advice. The Agent is a computer system, which locates in dynamic and complex environment, can astronomically sense the environment and act accordingly to complete its tasks or goals. Agent is a computing entity with four features of autonomy, reactivity, interaction and initiative. In the research on Agent, different researchers endowed Agent with different construction, context and capability in their own system so that they can conveniently work deep in a specific field [7]. In the context of spatial reasoning, the term agent is mostly used to describe an individual that performs a specific task as route advice [8].

Multi-agent systems can be identified by several rationales for distributing an AI system, such as adaptability, cost-effectiveness, and improvements in the development and management process [9]. In addition, they point out that the inherent isolation/autonomy of the parts provides not only protection for local information, but may also be a more 'natural' way to address certain problems. Further-more, they argue that the distribution facilitates specialization, and may increase the reliability, robustness, and/or efficiency of the entire system [10]. Finally, they state that resource limitations can be handled both on an individual, and on a larger scale.

Accounted for these features of Agent, it is natural to introduce Agent into the GIS system where it can be applied to such aspects as gathering of geographic information, downloading and transformation of geographic data, cooperation of geographic information service, system integration and individuation style design [11]. Agent offers a new method for computation and problem solution, which has many advantages as follows:

- Autonomy and reactivity: According to the internal state and outside environment Agent can run without the direct intervention of humans or others; it has some kind of control over itself. It can also get feedback information from the environment and then redirect its activities [12].
- Interaction: Agents can cooperate with each other. With the development of GIS applications, the functions of GIS become more and more complicated. So many problems cannot be solved by a single GIS system except for cooperation in multi-system. The cooperation of multi-agents can better resolve the cooperation problem of geo-graphic spatial information service functions and GIS application and improve the capability and efficiency of GIS service [13].
- Intelligence: Geographic information gathering consists of information searching and information filtrating. We can search and filer geographic information by means of Agent, which offers different services to different users, and can remain user's individuation characteristics and provide individuation style according to user's interests [14].
- Distributing: Agent system loosens the restrictions of centralization, close and ordinal control, and offers distribution control, dynamic emergency processing and parallel processing. GIS is just this distributed system.
- Reusability: Agent system can decrease the cost of software and hardware and offer a quicker method of problem solution. Agents can be used repeatedly. Therefore, most codes are shared and the complexity and construction difficulty of GIS are reduced [15].

3. The proposed architecture

The proposed architecture handled by the Geographic information system and based on Multi-Agent System based on blackboard architecture as shown in figure1, contains a set of software agents like the interface agent, the information gathering agent, the GIS agent and the agent control execution. These agents may run on one computer, and may be distributed on different computers in the network. Within the system, different Agents act as different characters, having different functions and tasks**.** To complete the GIS task, Agent needs to communicate and cooperate with other participants (such as users, other Agents or data sources).

The reasoning module has distributed hierarchical blackboard architecture (figure1) and based on a set of knowledge sources communicate through a multi-level data structure. The knowledge sources are structured in a three level hierarchy: Strategy, tasks and specialists. Each level represents a different view of the goal resolution space. The hypothesis is the basic data unit of the blackboard and represents a partial solution. The agents are invoked by the control mechanism in response to a particular change on the blackboard which is the event.

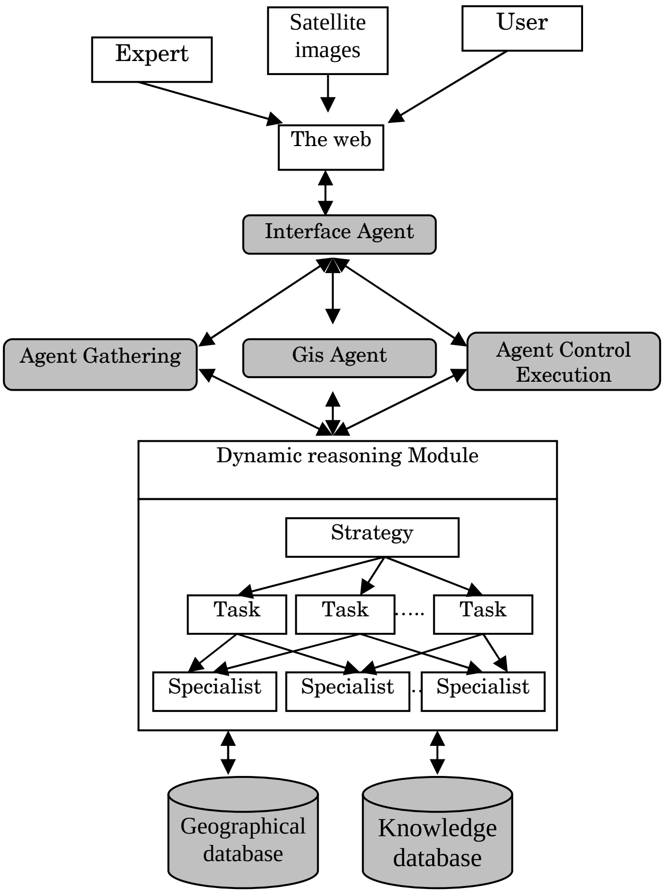

Fig. 1 Multi-Agent System Architecture.

Based on the model of MA system architecture above, the architecture consists of:

3.1 Interface Agent

Primarily, in this model, interface Agent is designed to achieve the interaction between system and users. It realized the generality of user interface. After requesting searching command, what you need to do is just to wait easily but need not know where the data source is or which server to access. Agent will do everything for you. And the system will return the well-processed data to users. So it has some kind of intelligence.

One advantage of interface Agent is that it is a friendly interface. You will learn to use it easily in a short time even if you are a rookie in GIS. The main functions of interface Agent include the describing user's searching request in some kind of fixed format, the vague-searching through communication with KDB (Knowledge Base) and the communicating with information gathering Agent and GIS Agent, submitting the searching request and returning the resulting data to user.

3.2 Dynamic reasoning module

The dynamic reasoning module (Fig. 2) is the center of intelligence of the intelligent control system. Strategies are received from the user control by the interface agent. The blackboard structure of this module consists on three abstraction level hierarchy: Strategy, tasks and specialists. Each level represents a different view of the goal resolution space. The hypothesis is the basic data unit of the blackboard and represents a partial solution. The agents are invoked by the control mechanism in response to a particular change on the blackboard which is the event (Fig. 3).

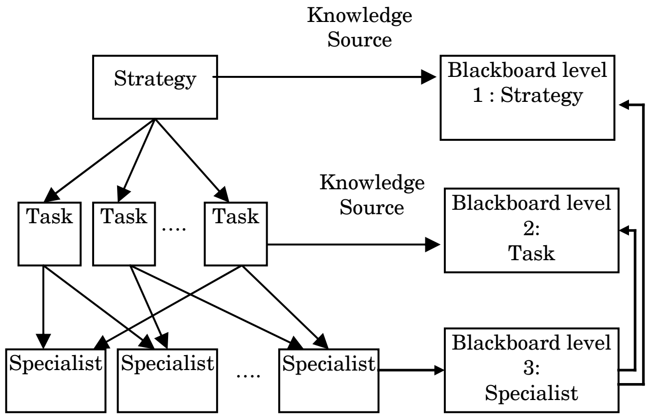

Fig. 2 Dynamic reasoning module.

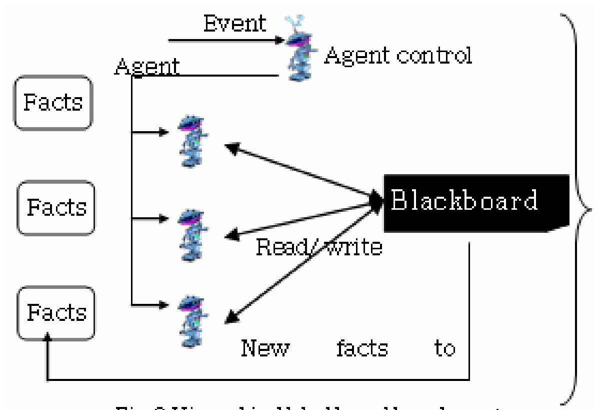

Fig. 3 Hierarchical blackboard based agents

The dynamic reasoning module performs the different reasoning phases. An initial planning phase determines the best strategy to reach the goal of the end user which is provided by a request. Each strategy is composed of a set of tasks and each task contains a set of specialist. An execution phase launches the agents. During this execution, the dynamic reasoning module determines goals and initializes some parameters. An evaluation phase assesses the quality and the contents of the resulting data at the end of each agent execution. If results are correct, planning can continue. If not, the result judged incorrect, a repair phase decides what following action to undertake, depending on the evaluation judgments.

3.3 Gathering Agent

Information gathering Agent is the Agent that searches and filters the geographic information, acting as an important part of the system. Information gathering Agent receives the client request from the interface Agent, and then searches. After getting the searching result, information gathering Agent will filter the information according to the user's interests and strategies stored in KDB. In addition, it will modify the personal interests of users and individualize them for later searching to be referenced. Other work, such as the downloading of geographic information, is in the charge of GIS Agent.

3.4 GIS Agent

The GIS Agent is the Agent with some specific function in the system, such as displaying Agent, analyzing Agent and downloading Agent. The creating process of GIS Agent is:

- The Interface Agent transfers the user's request to the dynamic reasoning module.
- The dynamic reasoning module searches the strategy that needs to be created according to the description of the request.
- The dynamic reasoning module creates the instance of GIS Agent.
- According to different system demand, we can flexibly design different kinds of GIS Agent to complete specific missions. System can be extended flexibly based on the specific requirement.

3.5 Knowledge Base

The knowledge database stores the embedded knowledge in the system and the rules defined by an expert. The different types of knowledge, such as data, programs and criteria are described in the knowledge base, structured by different concepts. The dynamic reasoning module uses the information in order to build a solution to give a goal. The efficiency of the supervisor is tuned by what kind of knowledge source is available in the knowledge base. The knowledge is described by:

Goals: represent an image processing functionality. It has the ability to test the result issued from the execution. Those are called: the evaluation rules as shown in Fig. 4.

Goal
Name: symbol
Functionality: commentary
Argument-In: list of arguments
Argument-out: list of arguments
Choice: list of rules
Evaluation: list of rules

Fig. 4 Goal compound

- Operators: describe actions that can be performed. They contain the information to satisfy goals.
- Arguments: list an input and output data.
- Requests: is a goal to be reached.
- Data description: information about an image like the size, the maximum pixel value or what the image contains.
- Context: General information concerning the application.

3.6 The Geographical database

The database of the proposed system contains a set of spatial-temporal data. A spatial-temporal object can be defined like a spatial object whose form and/or position vary with the time.

4. Detecting objects

In a multi-sensor system, the geometric aspects have to be computed depending on the sensor. Four main descriptions are used to detect specific objects and involve a priori knowledge on the specific type of object which is radiometric description, geometric description, sensor sensitivity and spatial relation. The radiometric description is generally a description of how objects appear in the image (a grey level interval, or a characteristic such as pale or dark). The geometric aspect of the object can be, for instance, a description of the geometric shape such as rectangular or round, elongated or compact shape, or a range of various dimensions of the objects. These four criteria can be used to detect an object by choosing the best-adapted algorithm, or to validate the presence of an object by matching computed sizes with model sizes.

5. Reasoning steps for image interpretation

In this section, we present the various steps of the system reasoning and precise which components are involved in each step:

- Choice of the images to work on, and of the objects to detect. It can be some kinds of objects potentially present in the scene, or all the objects known in the knowledge

base.
- Creating an ordered list of objects to detect using the user list, the object models, and the detection strategy. If an object is point-like, the system will detect first objects present in its context (even if the user did not ask for), and then use them to help detecting the point-like objects.
- Choice of the next kind of objects to detect.
- Choice of the most adapted sensor to detect this kind of object.
- Choice of the strategy to run using the request mechanism.
- Effective detection of the objects and requests to low-level specialists as a semantic object.
- Updating the fact base with the new detected objects, detection of simple conflicts, and eventually triggering of the agent conflict specialist such as conflicts requiring the use of the contextual knowledge at several levels to be solved: the conflict specialist is in charge of them, but when it does not find a solution, the user is eventually required to decide.

In order to validate our approach, we are carrying out the pre-processing of SPOT images with different filters. The study area is situated in center Tunisia (North Africa). The basic system implemented by a multi-agent system was each agent associated to an operator located in the operator base and provided by the engine [16]. As an input, the satellite images (as shown in Fig. 5 and Fig. 6) used in our application is provided from different sensor like XS1, XS2 and XS3. The first agent was an Agent classifier using unsupervised operators for classification provided by the operator base and evaluated by a Multi-agent Engine which combine facts and rules provided from knowledge base [17]. The output classified images (as shown in Fig. 5 and Fig. 6) represent for classes. These classes allow the extraction of principal objects. This information were given as an input to the Agent change Detection in order to detect the change occurred since 1988 in our zone of interest (as shown in Fig. 7).

6. Interpretation

We now present the results of the interpretation of a scene. A lake (Nabhana Lake) appears in centre of the scene. The upper zone is mountainous while the lower zone around the lake represents a high and low density of vegetation. To present the details of this running interpretation, we structure the steps as following:

Before the interpretation starts, the system asks the user which scene to interpret (here the Jbibna area), and the type of objects that have to be detected and assign the evolution occurred between the two dates in this scene. Let us assume the user chooses lake, river and roads.

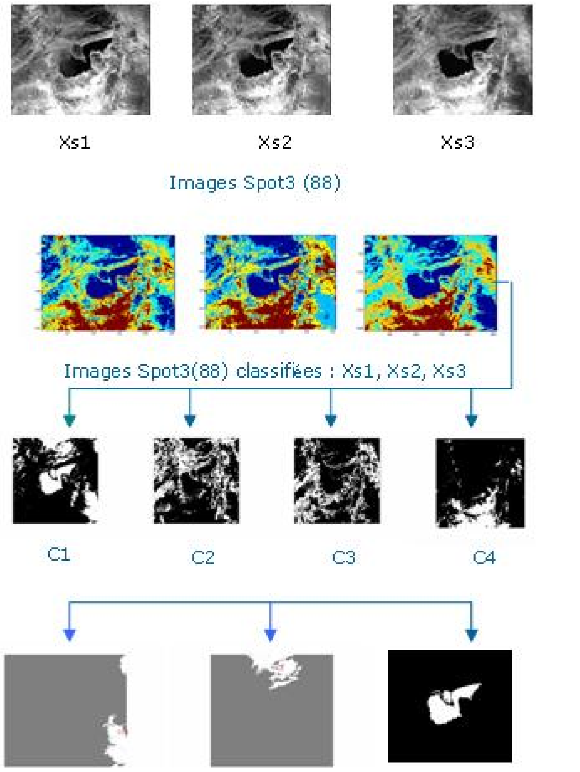

Fig. 5 Different phase of images classification 1988

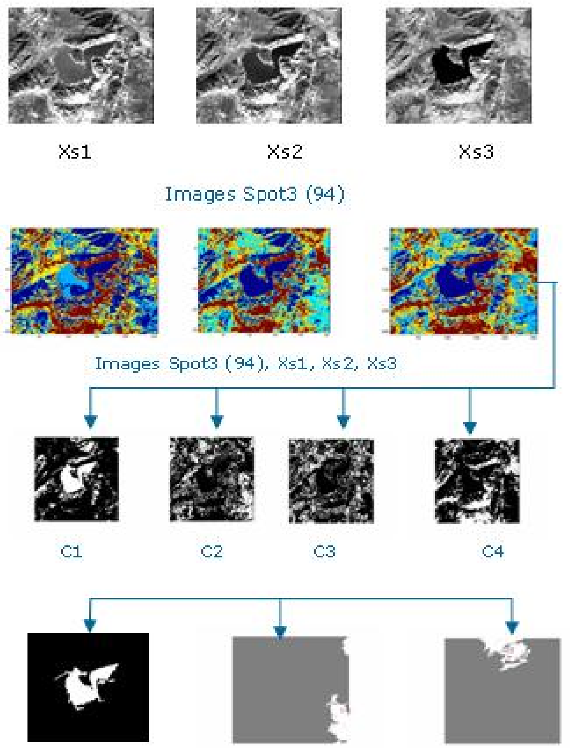

Fig. 6 Different phase of images classification 1994

The scene specialist adds to the list of objects to detect, the objects that are in the context of lake and easier to detect, that is rivers, mountains for example. The object list is then sorted using the strategy (salient objects have to be looked for first). Here, the list is: lake, road and river.

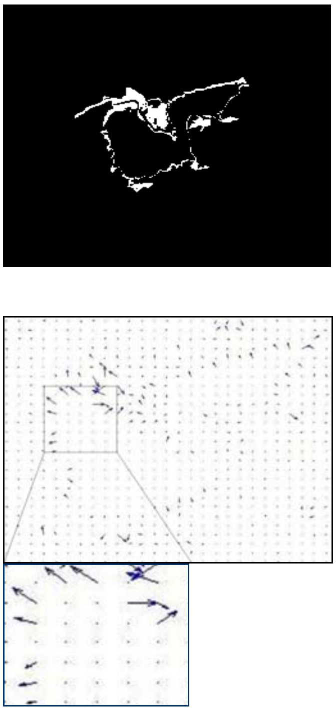

Fig. 7 Dynamic detection

7. Conclusion

There still remains considerable work in developing the framework described here. Agent communication, agent roles, agent cooperation and competition for resources, spatial dependencies all need further work. Model validation, transparency and the how the results will be used by decision makers are other issues requiring further exploration. These issues are the subjects of current research.

Agent technology gives us a brand new method to solve the problem. After analyzing geographic information and Agent, this paper proposed a model of geographic information gathering based on multi-Agent (MA) architecture and discussed the system construction. The prototype system with this architecture has the following features and advantages:

- System construction is flexible and extensible. Agent with different functions can be customized.
- Users can retrieve geographic information.
- Agent provides different searching strategies according to user's interests, and keeps the personal characteristics of the user.
- Improving the capability and efficiency of GIS service. Because of the limitation of system design and implementing method, the prototype system still needs to be improved. What is more, it needs further research for MA (Multi-Agent) system to be applied in practice. In addition, MA system lack of a standard of system architecture and organization, and efficient methods to construct and evaluate MA system.

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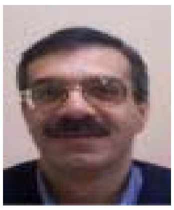

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