

# GeoSEMA: A Modelling Platform, Emerging “GeoSpatial-based Evolutionary and Mobile Agents”

Mohamed Dbouk, and Ihab Sbeity

**Abstract**—Spatial and mobile computing evolves. This paper describes a smart modeling platform called “GeoSEMA”. This approach tends to model multidimensional GeoSpatial Evolutionary and Mobile Agents. Instead of 3D and location-based issues, there are some other dimensions that may characterize spatial agents, e.g. discrete-continuous time, agent behaviors. GeoSEMA is seen as a devoted design pattern motivating temporal geographic-based applications; it is a firm foundation for multipurpose and multidimensional special-based applications. It deals with multipurpose smart objects (buildings, shapes, missiles, etc.) by stimulating geospatial agents.

Formally, GeoSEMA refers to geospatial, spatio-evolutive and mobile space constituents where a conceptual geospatial space model is given in this paper. In addition to modeling and categorizing geospatial agents, the model incorporates the concept of inter-agents event-based protocols. Finally, a rapid software-architecture prototyping GeoSEMA platform is also given. It will be implemented/ validated in the next phase of our work.

**Keywords**—Location-Trajectory management, GIS, Mobile-Moving Objects/Agents, Multipurpose/Spatiotemporal data, Multi-Agent Systems.

## I. INTRODUCTION

WORKING with unconventional spatial dimensions is a hard task. Day by day, spatio-referenced data are objects of several proofs. Such data provide a huge amount of knowledge, in which new features are included and thus they become support for futurist applications. Due to the advance in technology, multidimensional (e.g. spatiotemporal, etc.) data are solicited more and more. Mobile GIS applications as well as applications involving moving objects seem good computing examples for such kind of knowledge.

The fourth-dimension (4<sup>th</sup>D) leads to connect events with time; it helps, for example, in exploring some devoted stories; it also assists in simulating and predicting the future. Moreover, what about other dimensions if they exist? How many issues could be raised-up and resolved if other dimensions are discovered and involved!

In this paper, an adaptive modeler for multipurpose geospatial constituents, called “GeoSEMA”, is elaborated.

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GeoSEMA would be a conceptual platform tending to emerge multidimensional and unconventional geospatial data. In other words, it would incorporate energetic, dynamic and evolutive geospatial entities or objects. The considered objects or entities are vivacious and would look like what is called, geospatial agents.

However, “what kind of real applications such approach should support”? Practically, GeoSEMA tries to find out an adequacy between vitality of new and futurist dimensions and realistic GIS related applications. So, it should, for example, engender applications such as: ship trackers, some archaeological stories, guiding and tracking intelligent missiles, etc. GeoSEMA, requires and involves non traditional data and equipments, e.g. GPS, real-time data capturers and trackers; they should incorporate and mix some complex data models, mobile processing schemes and technologies.

The rest of the paper is organized as follows: in section II a contextual background is outlined and an overview of related work is discussed. Section III presents GeoSEMA basis. In this section, all related concepts are introduced and intensely considered. Some experiments that demonstrate and validate our approach are presented in section IV. Finally, the outline of future directions and conclusion are drawn in section V.

## II. RELATED WORK

In this section, an overview is mainly established about works done and are related to the GeoSEMA initiative. This section starts by over-flying the key concepts that have been considered and reported by our approach, e.g. location-based management, moving objects/agents, trajectory management, etc.

### A. Research Background

Location-management coupled with wireless communication and sensor technologies is fundamental for applications such as: air traffic control, mobile-electronic commerce, weather forecasting, etc. In spatial environments, geospatial-located objects that persist over time stimulate physical objects. Practically, humans deal and interact with non-intentional physical objects, either stationary (e.g., buildings, trees, etc.) or moving (e.g., animals, etc.) objects and intentional agents (e.g. with intentional states such as beliefs, plans, desires, etc. [5], [6]).

Working on moving objects may provoke issues such as

trajectory location-management [3], [4], road distance computation, etc. However, models characterizing spatial areas are graphs-based [2]. Approach modeling and predicting future movements sometimes apply a constrained network [9], instead of using Euclidean space representations.

Attempts to provide frameworks on locating and tracking moving objects in dynamic environments have been reported by many researches, mostly specialized in robotics [1]. A suitable spatiotemporal database prototype, incorporating trajectory model, and managing moving objects is proposed in [10].

Moreover, they are an interesting emerging approach, in some way, concepts requested by GeoSEMA. [8] proposes a multidimensional spatiotemporal data model by providing a uniform handling of different data types. The data model tends to integrate spatial and temporal data. It provides additional information to facilitate semantic interoperability and enabling spatial analysis (particularity: specifications evolve in this data model).

A universal abstract model for future movements of moving objects called "FuMMO" is proposed in [11]. In this approach, the author separates moving object models and prediction methods and tries to establish an abstract model as a conceptual basis in the area.

However, a confident moving objects data model, called "Balloon" model, is proposed in [12], [13]. This model deals with spatiotemporal changes, it provides an integrated support for both historical and future movements of moving objects. The "Balloon" model describes basic ideas presented in [11]. It incorporates formal definitions of moving objects regarding their movements over time (past, future). Whereas [14] is older than "Balloon" model, and rather than dealing with geometries changing over time and (2, 3)D, it invests in higher-dimensional entities where structures and behaviors are captured and considered as abstract data types. Such characteristics are integrated, in the model, as basic data types.

Furthermore, there is a trusted framework approaching spatiotemporal data called "Hermes" [15]. Hermes is intended to be a robust framework aiding spatiotemporal database developer in modeling, constructing and querying a database with dynamic objects. Hermes deals with dynamic objects that change locations, shape and size, either discretely or continuously over time. Hermes is seen as a data type-oriented model that satisfies and supports the representation of moving objects under an object relational platform. More specifically, Hermes has been designed as an extension to any extensible Object-Relational Database Management System (ORDBMS). Its main functionality is to support the storing and querying of complex data types such as the trajectories of continuously moving Intelligent Virtual Agents (IVA) [16].

Finally, interesting attempts, speaking about virtual-agents rather than speaking about moving objects, are found in the literature. [15] presents an architecture for multi-agent virtual environments that is based on a spatiotemporal database. An abstract representation of the environment and of the moving entities is maintained in the given architecture. This

architecture supports and integrates all sensorial information required by the agents. It adopts, for managing agents, the so-introduced Hermes.

### B. GeoSEMA and Other Works

Briefly, GeoSEMA emerges inside its constituents, and inherits from all the above works concepts and issues like: geospatial multi-dimensions profits, geospatial location-based facilities and opportunities, time dependent (spatiotemporal) issues and specification evolving, moving issues and related auto-tracking facilities, geospatial agent-based collaboration (inter-agents dialogue protocols), etc.

However, the multidimensional spatiotemporal data model presented in [8] tends to promote spatial analysis, in a context of evolving specifications. It narrowly applies the key concept of specifications evolution. Anyway, GeoSEMA tries to be more generic; it provides and applies an augmented evolution of specifications. In fact, considered objects, in our approach, are initially physical with additional capacities for becoming geospatial agents. They will stimulate hybrid agents (c.f. section 3.1.). Such geospatial agents should move according to some eventually predicted trajectories. Truly, GeoSEMA doesn't pretend to be specialized in how moving-mobile objects should be handled in their details. Practically, GeoSEMA pleads for extrapolating ideas such as trajectory management, seen in [8] in order to emerge geospatial agents in a constraint universe/space. Predicting future movement concepts are well presented in [8]. The abstract "FuMMO" model is so basic working with low level object geo-features; it could be extrapolated for becoming applicable by our approach.

In contrast to "FuMMO", the Balloon model [12], [13] pretends to emerge both historical and future moving-objects' movements. It seems more developed and could influence any future effort in the area. So, with respect to objectives fixed by GeoSEMA to deal with more evolved objects/agents, emerging an extrapolation of concepts and fundamental ideas issued by [8] regarding higher-dimensional entities is opted.

Finally, and very truly, the elegant approach-architecture presented in [8] and its Hermes, [8] seems to be a good and an accurate starting point for GeoSEMA initiative. [8] advances an architecture for multi-agent virtual environments that is based on a spatiotemporal database. Authors, in such approach, maintain an abstract representation of the environment and the moving entities. They also deliver all the sensory information required by the agents. However, rather than imitating the basic concepts of Hermes, GeoSEMA should, mainly, reflect the concept of multi-agent environment. It would be more expressive in terms of modeling collaborations between well-promoted evolutionary-geospatial-agents.

## III. GEOSEMA PLATFORM

GeoSEMA is an applied conceptual platform, which tends to represent and models an n-dimensional geospatial evolutive

digital universe (also called space). Geospatial designers could, conceptually, be able to readapt/map such platform in order to build up their specific applications. GeoSEMA can be seen as a geospatial-space design pattern.

However, GeoSEMA is, in practice, supposed to characterize a huge and complex geospatial-referenced space. Conceptually, the nature of such space and, exaggeratedly, of its constituents may evolve/vary from time to time depending on some characteristics (e.g. wintry, sunny). It may also evolve depending/according to some expected and/or predicted events (e.g. extra attacks, earthquake, etc.). So, this space is difficult to manage. It could, abusively, be characterized using parameterized devoted features (e.g. velocity, degree of infiltration, etc.). Features characterizing space' geospatial constituents (become geospatial agents) are about: behaviors, 3D (geospatial) representations, chronological effects (time-stamping variations), lifetime (potential energy), interconnectivity, etc.

Consequently, the GeoSEMA approach promotes some basic abstract constituents. It conceptually deals with three main ingredients and principles:

- features setting-up the space itself,
- a classified set of geospatial evolutive and mobile agents,
- a set of behavioural rules governing and materializing potential any inter-agents interactions (extra-events).

The considered geospatial space is seen as an unusual agent for grouping, collecting, associating and coordinating a huge amount of collaborative geospatial agents,

Finally, an algebraic and conceptual vocabulary describing the GeoSEMA formal definitions are used and given in the following sections.

#### A. Geospatial-agents Abstraction

Why dealing with so-called agents? The objects, that GeoSEMA considers, are unconventional objects. They should be intelligent, stimulating geospatial agents.

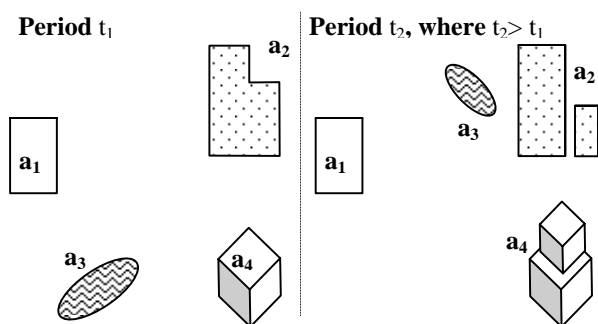


Fig. 1 Abstraction of geospatial-agents shown at two different periods

However, GeoSEMA agents should be able to move (moving/mobile agents), navigate within the expected space (e.g. ships, missiles, etc.), interact (inter-operate), etc. They should be reactive having passive or reactionary information. Passive information have no direct influence on the agent

itself. It will be informative description, while the reactionary characteristics means that changes on such features (reflecting some incoming extra-events) may provoke changes on the entire agent itself. The given agent may reappear with another profile (Fig. 1; agents: a2, a3 and a4).

Agents in this approach may be so complex rather than usual characteristics such as: information materializing some complex representations (spatiality, incorporated dimensions, timestamp, porosity, etc.) and behavioral descriptions,

Abstractly, the geospatial-agents, considered by GeoSEMA, could reflect and mimic the Observer/Subject (in java Observer/Observable) design pattern [17], [18], [19]. So, GeoSEMA approach distinguishes between two principal categories of geospatial agents:

- Agents of type Base or Base-Agents (B).
- Agents of type Receiver or Receiver-Agents (R).

A **Base-Agent** is intended to manage (administer, coordinate, monitor, track, etc.) a devoted group of Receiver-Agents. It will be seen as a back-agent applying one dedicated protocol. It may, for example, order to its Receivers some tasks and requests. Such kind of agents may, sometimes, stimulate an adapted computer system supporting one central repository (archiving all prescribed evolution).

On the other hand, a **Receiver-Agent**, is seen as front-agent and should continually be associated (having connection during one delimited period) to some Base-Agent. So while having a unique id (AID) GeoSEMA world-wide, should operate in adequacy with its punctual Base (to which is associated). It may from time to time ask for new missions and for any useful information. Also, it may transmit to (tell) the Base some valuable/helpful data.

Following, a short and brief list of properties and some

TABLE I  
 GEOSEMA PROPERTIES AND CHARACTERISTICS

Property / Device	Description	Base Agent	Receiver Agent
Info	Descriptive information	✓	✓
Geospatial representation	2d or 3d geometric/geographic and spatial representations	✓	✓
tsp, age	Time/date features stamping agent's reactions reflecting some prescribed rules.	-	✓
...	...	...	...
life (mobility)	Amount of life or potential energy. An integer, applicable values: $\{-\infty, \geq 0\}$ . Positive value determines the potential mobility, while " $-\infty$ " means that the given agent is anchored	-	✓
Links	Implicit and explicit associations (semantic, etc.) relating and connecting any kind of agents	✓	✓
repositories (storage)	Incorporating and archiving, all kinds of, information requested not only for local processing but also for general purposes; on agent timed-views, etc.	✓	depends
Computer tools / devices	An elected and dedicated contextual tools and devices may support any smart agents	✓	✓

devoted devices that could characterize the GeoSEMA agents:

### B. Inter-agents Operability Abstraction

Mainly, agent's behaviours reflect and/or materialize some extra-events. An agent may represent the subject (receiver) for a given event; e.g. an extra-impact such as earthquake may demolish buildings and break-down some bridges, or it may play the role of an invoker for some event; e.g. flooding (river overflow).

In GeoSEMA, events may influence and stamp agents. They could be internal or external. In both cases, events should be analyzed, characterized, timed, indexed and then itemized/materialized within a dedicated repository as smart rules (Fig. 2); smart rules constitute (compose), together, a huge amount and open set of behavioural rules.

Finally, the geospatial space that GeoSEMA considered will formally be characterized by using some elegant algebraic vocabulary.

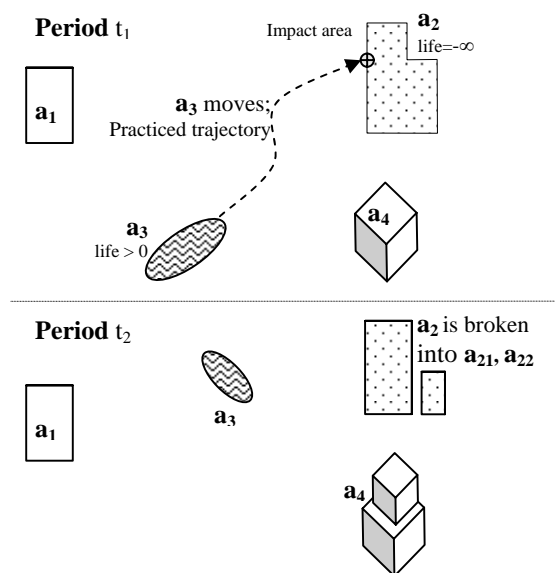


Fig. 2 Abstract analysis of events in GeoSEMA

Formally: Geospatial space is a triplet, it will be defined as follow:  $S \langle D, A \langle B, R \rangle, E \rangle$ , where;  
 S represents the workspace itself,  
 D represents the workspace descriptor,  
 $A \langle B, R \rangle$ : agent (bases and receivers) sets,  
 E: set of event-based rules, for example:

- an event  $\varepsilon(r_1, r_2)$  between agents of type "R" may generates a sequence of re-writing operations:
  - write a new version of agents;  $r \leftarrow r'$
  - remove agents;  $r \leftarrow \phi$
  - replace an agent "r" with new collection of agents; " $r_1, \dots, r_n$ ", e.g.:  $(r \leftarrow r') / (r \leftarrow \phi) / (r \leftarrow \phi, r_1, \dots, r_n) / (r \leftarrow r', r_1, \dots, r_n)$ ,
- an event  $t(b, r) / t(r, b)$  between one agent of type B and an agent of type R ; such (transmission) operation

could materialize and implement a coordination protocol between one Base and their Receivers.

However, the amount of event-based that governs it is very huge. The designer could prescribe which are, contextually, useful.

### C. Conceptual Modeling

In the modeling phase, the object-orientation technology (UML-Like) is the more adapted modelling methodology. Practically, GeoSEMA data model (Fig. 3), mainly, regroups the following foundation GeoSpatial classes: spaces "GS-Space", agents "GS-Agent", protocols "GS-Protocol" and events "GS-Event". Each one has an important role to play; e.g. communication between agents must apply an adequate protocol, while interactions between agents should reflect some prescribed events, etc.

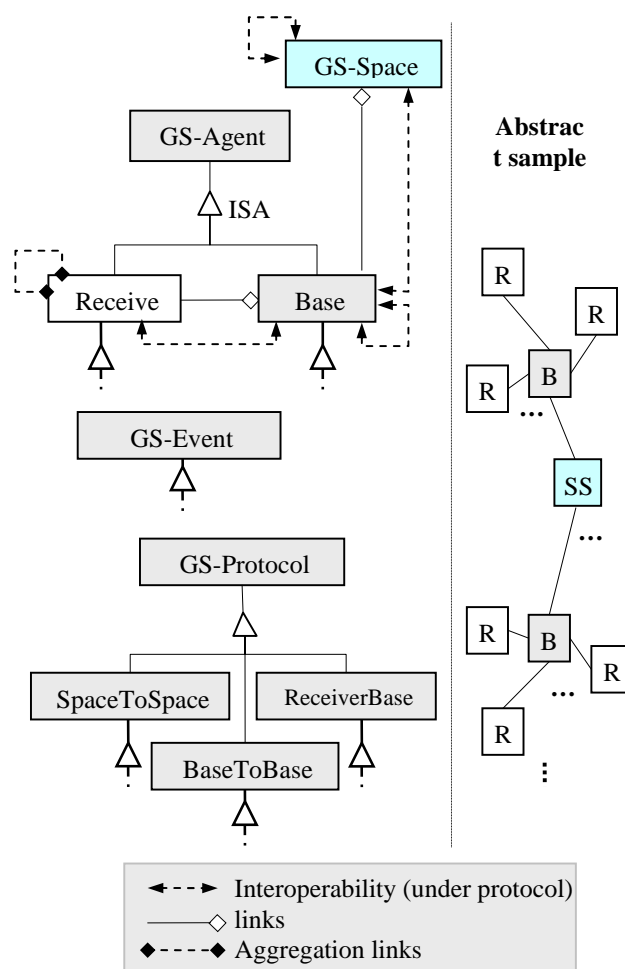


Fig. 3 GeoSEMA UML-like conceptual model

GeoSEMA conceptual model has to be an open model. It represents an abstract basis (framework) for Geospatial-like applications. Designers familiar with design patterns principles [17], [18], have to define and specify all domain-related agents, protocols and events. Specific agents, for example, should inherit from "Receiver" and/or "Base"

classes.

#### D. GeoSEMA Prototyping

The GeoSEMA approach is seen as a platform stimulating and emerging GIS-like tool and advanced data-distribution and mobile technologies. It is a well-founded framework intended to engender several class of temporal/mobile geospatial-based applications. Designers should be able to project and map adequate cases. They apply GeoSEMA basis in order to produce a compatible platform.

##### 1) Domain-related applications

Practically, the question that arises is: “which kind of realistic applications that GeoSEMA covers?” Following are some samples:

- 1) Marine navigation tracking: merchant ships are, for example, considered as moving agents following pre-elaborated/evolutive trajectories. Here, ships may be equipped with GPS and dedicated materials and tools. They should continually transmit/receive key-data to/from the base. Consequently, trajectories may be corrected / adjusted according to instantaneous and punctual analysis.
- 2) Site (City) histories: site can be any identified place; modern city, archaeological site, campus, medical-complex, industrial-complex, construction site, volcanic site, etc. Vital sites have stories and histories (images, video, maps, etc.). Such information should be recorded / archived against time. In some cases they, become critical and well-important. Tourism domain, for example, could have direct benefits.
- 3) Army war-like applications; guided-war: missiles can be seen as moving (smart) agents. Missiles should have trajectories (e.g. ballistic missiles). Trajectories for guided missiles may evolve. In other word, targets like buildings, cities, etc., may have stories before and after, for example, by-missiles attacks.
- 4) Person (prisoners) tracking: using remote-sensors (e-ring; electronic transmitter), Identified persons play the role of receivers. They could continually be tracked by one base.
- 5) Biomedical, atomic and molecular domains, etc.

The above samples demonstrate how such domain is enormous and prove that each element considered in the proof has its own influence and time is the more conclusive characteristic.

##### 2) A rapid prototyping

One, valid, software architecture tending to prototype GeoSEMA opts for a hybrid solution. It's about centralization and distribution of charges over one main computer system called “GS-Space” and a several nodes of type “GS-Base” (Fig. 4).

GS-Space consists of a devoted GIS-like enterprise manager. It might have some dedicating tools and devices. It could also support and materialize end-user prescribed inquiries; e.g. archiving issues, browsing and exploring the

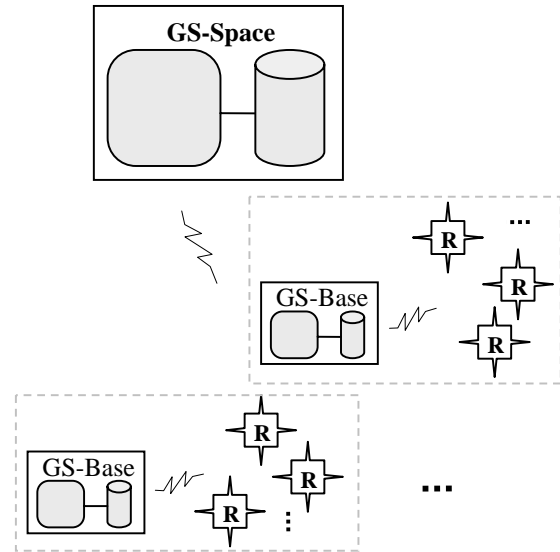


Fig. 4 GeoSEMA global and prototyping software architecture

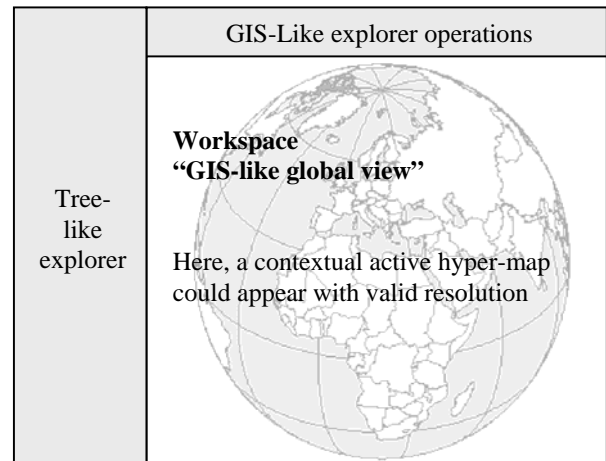


Fig. 5 GeoSEMA browser: an enterprise manager prototyping

space of related agents, etc. On the other hand, a GS-Base consists of an autonomous remotely monitored computer system. It could support and sustain an elected set of agents of type Receiver.

However, GS-Space, GS-Base nodes and geospatial receivers could (remotely) interoperate according to some prescribed protocols.

Distinctively, the GS-Space front-end could incorporate any kind of user interactions, e.g. zooming through links relaying geospatial agents, navigation through semantic relationships, browsing agents' versions, etc.

By emerging data, GS-Space operates as a simulator. It may generate, monitor and track some evolutionary operations. It could engender a variety of scenarios, and end-users can rework (refine) and elaborate adequate scenario-models.

GS-Space' explorer (Fig. 5) should be seen as a predictable support and also as a decision-makers-computer-aided tool. It may provide quantified / optimized alternative scenarios.

Such explorer (user interface) could mainly contain a

layered workspace and a tree-like dialog box. End-users could easily interact, manipulate agents, elaborate and fix scenarios.

#### IV. CONCLUSION

The advances in technologies in addition to the emergence of new features continue to enrich geospatial computing.

In this paper we tried to emerge features and concepts characterizing evolutive geospatial space and agents e.g. geospatial and temporal properties, multi-dimensions, dynamic and moving aspects, etc. We demonstrated that a powerful modelling platform could, once again, be produced.

The approach "GeoSEMA" presented in this paper represents an initiative leading to provide an open and flexible modelling framework. Instead of dealing with geospatial objects, GeoSEMA deals with so-called geospatial agents. Intentionally, geospatial agents are intelligent. They should move, interact (inter-operate), evolve, etc. They are divided into several kinds (Base-Receiver). Designers of specific cases (applications) should expand/map the above data model by integrating any specific geospatial agents (application related agents). They could also benefit from the above rapid prototyping software architecture and be able to build up their own applications.

Finally, we observe that some additional issues remain to be explored such as inter-operating protocol specification. However, we believe that the main contribution of this approach is the introduction of "a well-defined" modelling platform; as an integrated formal basis and a firm foundation for evolutive and mobile agent-based geospatial computing".

Consequently, to experiment the GeoSEMA approach, we plan in the near future to realize / implement and validate the above prototype by providing a real and coherent environment.

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