UsualSpace: A Smart Framework to Support Evolutive-Agents

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Abstract— This paper stands for a methodical framework to model and explore evolutive agents (e.g. Factories, Hospitals, Sport-Centers, etc.). Agents share same space; they evolve, interact and transit. They are inter-dependent, and have analytical state-full's characteristics/dimensions. The framework provides solutions for analysis and prediction, it aims to support an analytical methodology that shows; how agents evolve, how evolutions propagate, etc. Finally, key features, that illustrate the "UsualSpace navigational framework" basis and foundations, are deeply exposed in this paper, and also experimented through an instructive case study.

***Index Terms*—Evolutive agents, Hyper-space modelling, Multi-State modelling, GIS-like frameworks, Business intelligence**

I. INTRODUCTION

Things evolve, everything evolves in the nature and changes state, e.g. an employee may get new position: manager, president, etc., a town may become "City", construction sites, volcanic sites, etc., may have continuous stories and histories; they evolve continually.

Dealing with unconventional evolutive space is hard to undertake and reveal great challenges. However, the advance in technology and multidimensional and business-intelligent analysis offer a reliable support.

Concepts of evolutive-space reside in lots of real-world events and business activities; environmental risk related issues, e.g. flooding, forest evolutions, agricultural activities, are typical cases.

Our research in this area started with "MSpace" platform [1] in which, agents are of same type, e.g. hospitals, or patients, etc. The space is itself considered as one business environment (thematic layer).

The ultimate goal of the second working phase was to enhance and enrich the MSpace platform, and to provide one unified framework to model and explore that we call "evolutive usual-space". This space is intended to emerge heterogeneous evolutive-agents.

The duty is to devise a strong and firm methodology for building and stimulating evolutive-spaces. Hyper-space concept and characteristics are deeply considered; the space is complex and multi-layered; towards an analytical navigation strategy. The framework aims to provide a methodology to illustrate how agents evolve in space, how agents influence each other, how evolutions propagate, and also aims to provide solutions for analyzing and predicting agent's new-states.

The paper is organized as follow: in section II we outline the problem statement and an overview of related works is also given in this section. In section III, Evolutive-space (also called UsualSpace) framework foundations and basis are deeply considered. Modelling theory and navigation as well as end-user solution are presented in this section. An experimental case study is given in section IV. Finally, the conclusion is given in section V; the future work is outlined and drawn in this section.

II. PROBLEM STATEMENTS AND RELATED WORKS

In real-world, a business space is usually complex and agents have specific categories; they may interact and influence each other. The "Health-Care" space, for example, involves agents' categories like patients, hospitals, and factories. Moreover, a patient is affected by the pollution generated from a near factory, he is also affected by the hospital type and rating where he settling for medical care, and a hospital rating is affected by the food rating of its main kitchen, and by the doctor competencies that are contracted with, etc.

Here the space may contain heterogeneous and inter-dependable and evolutive agents; it is complex and hard to undertake. The concept of subdividing the space into bordering areas/subspaces and or applying the multi-layering (thematic sub-spaces) approach is helpful, but requires deep modeling efforts. The idea, indeed, behind

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this case is to exhibit the big challenges that we are facing where the space is qualified as complex.

The prospected framework must provide solution for space that contains multiple agents' categories and take into consideration the inter-dependability between spaces, the influences between agents themselves. The solution also must provide detailed and firm terminology to how to build such complex spaces, how to analyze and how to predict more accurately.

Obviously, dealing with evolutive-agents is sometimes synonymous to deals with moving objects or agents on one hand and to consider the spatiotemporal dimension/concept on the other hand.

The FuMMO model proposed by [2] works indeed with geo-features, the moving objects data model "Balloon" [3] deals with spatiotemporal changes; it provides an integrated support for both historical and future movements of moving objects. In contrast to basic "FuMMO" model, "Balloon" states for emerging both historical and future moving-objects' movements.

"Hermes" [4] deals with dynamic objects that change locations, shape and size, either discretely or continuously over time.

In the land use model presented in [5], the authors use discrete irregular objects as an autonomous spatial entity. They use the basic elements of Cellular Automata: space, neighbourhood, and transition rules, state, and time, and demonstrate that the proposal can be considered as a new paradigm for urban simulation. Here, the world is considered as a series of entities located in space. An autonomous active object or agent is a digital representation of all part of an entity. In this model, the transition rules specify the behaviour of cells between time-step evolutions, deciding the future conditions of cells based on a set of fixed rules. However, the state of the object changes is based on the adaptation of an entity to its environment. Also the time variant is considered as an element in this approach.

Ref. [6] Stands for "Adaptive Object-Model Evolution Patterns". It is a software architectural style that represents user-defined entities, attributes, relationships and behavior in an object-oriented domain model as a meta-data. Meta-data Interpretation is at run-time. Two patterns are described in their model; one is 'break and correct' which is used to guarantee consistent changes to an evolving adaptive Object model definitions, the other one is 'evolution resilient scripts' that enables the refinement of AOM type definitions without having to change in the scripting code.

In "Evolving objects in Temporal Information Systems" [7], authors presented a firm semantic foundation for a modeling language able to express both time-stamping and evolution constraints.

To conclude, the UsaulSpace framework that we propose inherits concepts and methods from our early approaches [1], [8] and [9]. It differs from the above listed approaches, first by introducing the concept of multi-state agents, and applying a multidimensional modeling and analysis. UsualSpace deals with business-patterns (business profiles), in which dimensions are combined. And second by introducing a firm "inter-agents dependability" solution (by adding the so called hyper-features, and functionalities) and applying the concept of Observer/Observable design pattern framework.

III. The UsualSpace Framework

The space that we consider stimulates a usual-space/universe behaviours, it deals with unconventional scheme and emerges and integrates huge set of agents. Agents in this space are heterogeneous (figure 1), expected to interact, move, transit (from state to state), navigate, etc. Rather than temporal and location-based characteristics, they evolve in well organized behaviours. Agents' behaviours reflect and materialize internal and/or external events

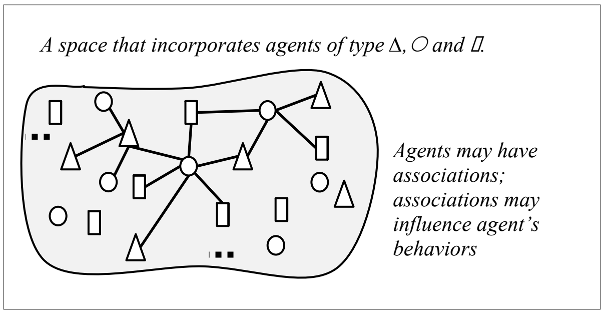

Figure 1. Typical space and heterogeneous agents

Formally, a usual-space is subdivided by agents-categories / families into several thematic subspaces, previously called MSpaces (full definition of MSpace platform is given in [1]).

A. MSpace; a Thematic Subspace Platform

The early MSpace [1] incorporates and considers a collection of evolutionary agents of one specific category; it emerges multidimensional data. Agents from one mspace have structural features/dimensions, and are tracked according to behavioral features (transitions, business rules).

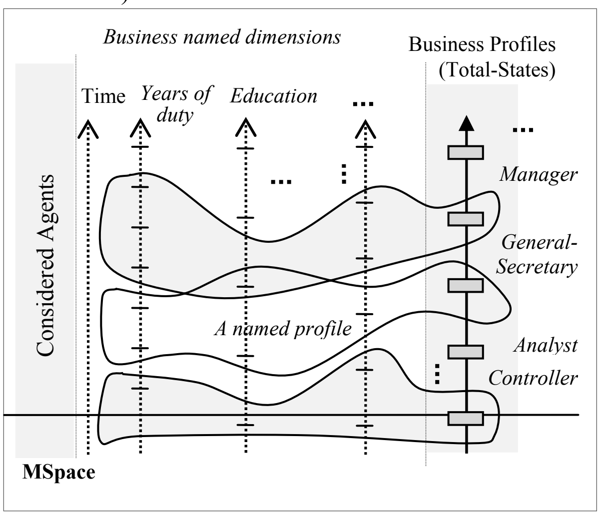

Figure 2. MSpace platform[1]; Case-study "Human Resource"

The MSpace consists of an integrated analytical tool, it deals with business named patterns (business profiles, figure 2), in which dimensions are pre-combined. The ultimate goal of “MSpace” was to enable agents’ evolution tracking and monitoring. The duty is always to predict, direct and ultimately correlate agents’ behaviors and activities.

B. Hyper-space Characteristics

Agents from an evolutionary space are intended to influence each other. An evolutionary agent (also called receiver) may depend on other agent/s (called master). Accordingly, mutual oriented associations are established between agents of type master and those of type receiver. Consequently, huge inter-agents dependability network could be established, it represents a derivation /instantiation of an extrapolated network called “inter-agents dependability diagram (IADD)” (figure 3). An IADD consists of an oriented graph; nodes represent the involved mspaces and the arrows represent the inter-dependence relationships between agent-instances.

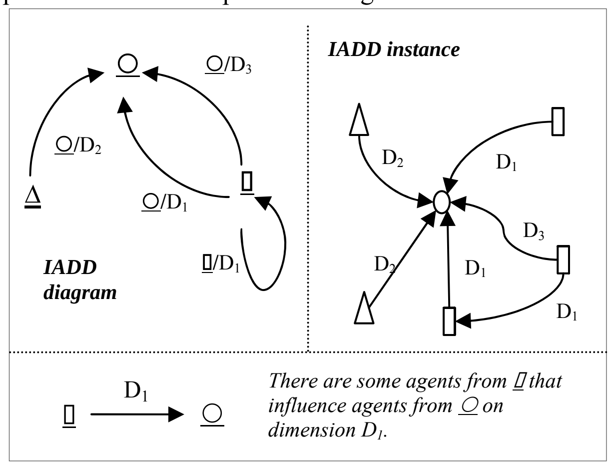

Figure 3. Inter-agents dependencies diagram (IADD)

However, when a master-agent “▯” or “Δ” evolve, it could affect (influence) all dependent receiver-agents “○” (figure 3). Based on the mspace firm foundations, the receiver-agent evolve throughout dimensions, consequently:

- A master-agent affects receiver-agents on one of their pre-defined dimensions. Arrows in dependability-diagram should be labeled with the given dimension from the receiver-agent.
- Master-agent may affect receiver-agents on many dimensions.
- Master and receiver agents may belong to the same mspace, towards reflexive dependability.

C. Agents Inter-dependability Modelling

Associations linking master-agents and receiver-agents are of type event-driven, they will be materialized using the Observer/Observable design-pattern. Here, receiver-agents play the role of observers, and variations or evolutions on one master-agent are triggered. Consequently, local-transitions from state to state of a receiver-agent (on the given dimension like D2, figure 4) are now directly linked to the master agent’s total-transitions (tracked in the given mspace; business-profiles).

Formally;

Consider that Δ is a master-agent / observable pre-declared in mspace Δ (e.g. Δ: Δ), ○ is a receiver-agent / observer pre-declared in mspace ○ (e.g. ○:○), and Δ influences ○ on dimension D2.

Protocol:

1. Δ Transits form local-state to a new state, consequently, a new total-state should be generated in Δ.
2. The new Δ total-state (business-profile) is observed by ○ and triggered.
3. ○ Applies a dedicated transition-function “○.D2τ”, it analyses the Δ new total-state and decides to transit from its old local-state to another state on the given dimension, it should generate a new total-state in○, and then new business-profile may be generated as well.

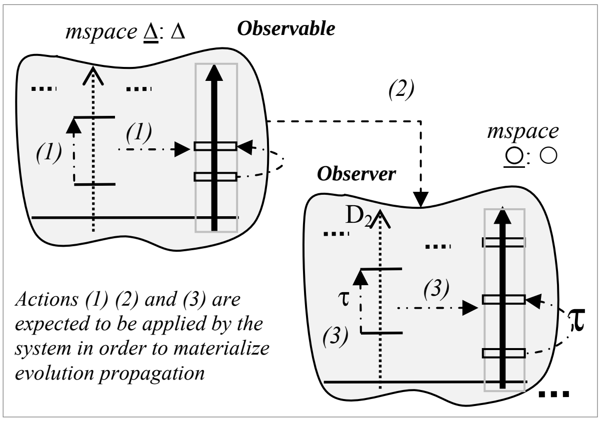

Figure 4. Inter-agents evolution propagation

Transition-function generalization:

○.D2τ(Δ); transition of agent ○, on dimension “D2” taking into account the evolutions of agent Δ.

More general:

- ○ may be concerned with more than one agent Δ; example ○.D2τ(Δ1,Δ2,…, Δi,…, Δn).
- ○ may be linked to more than one agent-mspaces; here an aggregation “Σ” must be applied: ○.Σ(Diτ(…)).

However, those dependability functions are domain-dependant and should be written by domain analytical experts.

Dynamic aspect:

According to the above IADD (figure 3), consider that agent ○4 depends on {<Δ1, Δ3, Δ5>, <▯1, ▯4, ▯6>} , and the new agent ⌂2 depends, in its turn, on ○4, the following scenarios should be considered:

- *On cascade-evolution*; if one of {Δ1, Δ3, Δ5, ▯1, ▯4, ▯6} evolves, the ○4 should be affected and may change state. Consequently, ⌂2 will (by transitivity) evolve as well, and so on. All related agents will evolve, toward on cascade-evolution.

- *Dependability-pertinence*: agents evolve continually, after each evolution-round, the IADD instances should be re-examined and evaluated. As a result, ○4 for example may lose (become free of) some links, and also new links may re-appear with respect to the pre-elaborated IADD, e.g. ○4 ← {<Δ1, Δ5>, <□1, □5, □6>}.

D. Prototyping and Navigation Issues

The early mspace platform [1] consists of a set of pre-elaborated visual and analytical operations. Based on the given IADD property, each mspace is represented as a full-analytical node, and the inter-dependability links represent the firm foundation of two additional paired operations:

- *Navigation throughout mspaces*: allowing end-users to explore the whole considered space, and to discover mspaces one by one, this is to materialize relationships "master-receiver" influences, e.g. Δ1→ ○4.
- *Analytical zooming*: this is to explore a given agent or mspace and going forward on a specific dimension. Here, the end-user must be able to discover and learn about the transition-modalities.

The UsualSpace framework is given a dedicated enterprise manager (figure 5), in which, design issues as well as end-user operations are strictly materialized. As a result, the IADD is, continually, considered as the main display (figure 5) that summarizes hyper-space new essential operations.

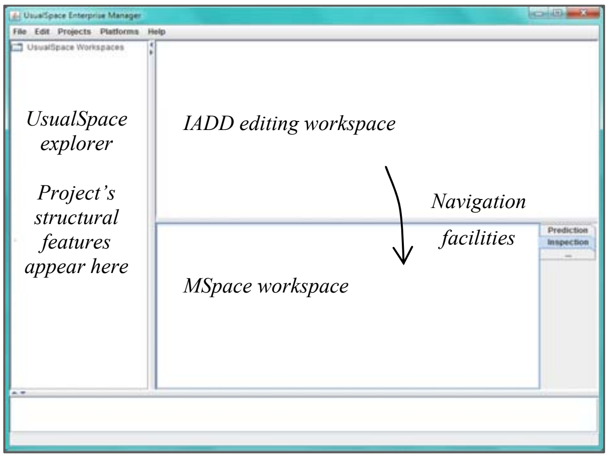

Figure 5. UsualSpace enterprise manager prototype.

IV. Experiments and Observations

A. UsualSpace Building Process

The building process is software-engineering-like, it requires key persons to be applied, and they should emerge technical-skills as well as deep knowledge in the considered business-domain. The process consists of the following:

1. Identify and name the relevant agent-mspaces,
2. Analyze and find-out the inter-dependability relationships that relate the above mspaces,
3. Put mspaces and relationships together in a unique diagram "IADD",
4. Add details to the considered mspaces; provide the descriptive and analytical features and dimensions,
5. Re-adjust the above mspaces according to the founded relationships, and assign labels/ dimensions that characterize those relationships,
6. *Implementation phase:*
   a. Draw up (pseudo code) the transition-functions one by one.
   b. Put the given IADD onto operational platform.
7. Apply analytical and predictable scenarios.

B. Case Study

Consider the case of patients (Health-Care as business domain) tracking and monitoring. Practically, many factors may affect patient's health; the hospital that he may stay in, the air quality he's breathing, the noise pollution percentage, and his body conditions, etc. For example, the air pollution percentage threshold as well as noise pollution must not be exceeded in the area where patient is settling for treatment. He must exercise sports to regain his health. Patient also must be treated with empathy by the surrounding people. Also he must not be given un-certified medicines. The home-residency as well as the hospital or the medical care centre must be located far from highways, factories (air and noise pollution) etc. Sports centers around hospitals or inside must have the basic equipments, etc. However, the conceptual analysis leads to consider the following MSpaces (figure 6): "Patients or Human Health", "Hospitals or medical health care" and "Medical-Laboratories", "Agriculture-Zones" and "Factories", "Sport-Centres", etc. Each of which relates (labelled with) some patient's analytical dimension.

Patients' MSpace structural details (figure 6):

- Pollution: [0-100]%
- Body conditions: tired, needs exercise, good shape, healthy
- Medical Treatments: bad, fair, good, very good
- Applied Medicines: critical, good, very good
- Infection factor: [0-100] %
- Food Safety: critical, bad, fair, good, healthy

Business Profiles: Discharged, Progressing well, Comfortable, Stable, Satisfactory, Critical but Stable, Critical, Decreased.

Now let's identify functions that define the dependability between agents in these mspaces:

A patient health is dependent on:

- Pollution State: function (Agriculture Zones, Manufacturer); agents from factories affect the pollution state/dimension,
- Body Condition states: function (Sports Centers); agents from Sports-centers affect the body conditions state,
- Medical Treatments: Function (Hospital); agents from Hospitals affect the state 'Medical Treatments' dimension of Patients.
- Infection Factors: function (Hospital, Factories); agents from hospitals and factories affect the dimension 'Infection Factors' of patients.

- etc.

Note that, the exact functions – or mathematical functions should be provided by subject matter experts in this field. Once provided, we can define them in the system for doing the right calculations. Another issue is about the used data which is not so accurate and totally correct, it is just gotten in order to run some specific scenarios, but it does not reflect real life knowledge.

Scenario:

The Selata factory made an enhancement and has been able to get an international certificate for being 'pollution friendly factory'. This came after the noise pollution have been reduced from 75% to 20%, the toxic chemical exposure have been reduced from 90% to 25%, and the CO2 emission from 92% till 20%.

Using our methodology, Selata factory agent changed 3 local states and has gotten a new 'total state' in its related MSpace 'Factories', which solicited an enhancement in its business profile, and thus it has gotten 'Good' instead of the old one 'Action Required'. Thus, applying the observer/observable design pattern, as the observable 'Selata factory' has evolved, the observer 'Albert' patient re-evaluate its functions of dependencies, and thus, invokes a direct evolution from its local state '40%' for the dimension 'Pollution' onto the new dimension '20%', and another evolution take place for the dimension 'infection factors' where a new local state '50%' instead of the local state '20%'. Moreover, this new total state for the patient 'Albert', will invokes a recalculation of its own defined function, and may get a new business profile, where he evolve to 'Stable' instead of 'critical but stable' (figure 6).

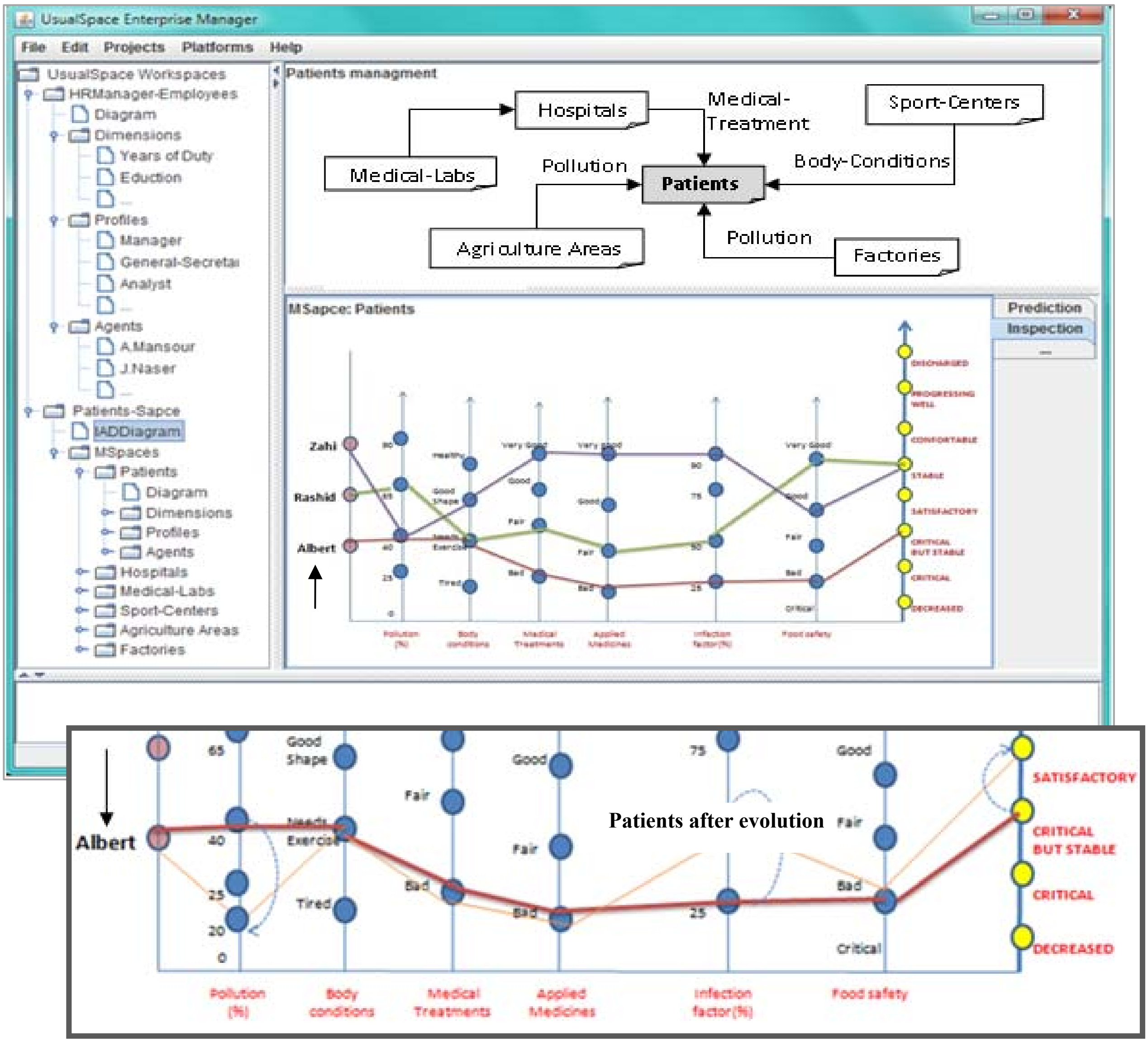

Figure 6. The UsualSpace Enterprise Manager - Patients tracking case study.

To conclude, first conceptual experiments show that, extra-agents could be grouped/aggregated into some abstract–agent-types, this is because those extra-agents share (influence) same analytical-dimensions, e.g. "Climate-agent" may aggregate "Agriculture Areas" and "Factories". Finally, the experiments also show that we are pressed to deploy additional efforts that lead to implement the above theory and concretely validate the delivered process.

V. CONCLUSION

The work consists for designing a new methodology for modeling evolutionary space and agents. We stated, in this paper, for an emerged framework called UsualSpace combining both MSpace and Hyper-MSpace previous approaches. In MSpace [1], we founded a basic theory and terminologies needed for modeling a space mono agent type. Then Hyper-MSpace [8] came to extend MSpace for being able to support spaces with agents from different categories can co-exist and influence each other. However, new terms and functionalities for building and manipulating usual spaces were tightly defined; we divested, as a result, a complete space building process. After that, we created a complex scenario on one experimental case study and showed how evolution works, how agents inside some mspace change their business-profiles by responding to some external events. Finally, the experiments show that the proposed methodology could be used to extend the UML state-transition modeling methodology. That is what we plan to investigate and explore in the near future.

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