Framework for M&S with Agents (FMSA) in regard to Agent-based Simulations in Social Sciences: Emulation and Simulation

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The original question

- Facing the recent challenge of creating a UAMA (Universal Automated Modeler Agent), i.e. :
  - "The challenge of creating a fully automated modeler/simulationist that can autonomously carry out all the separate functions identified in the M&S framework as well as the high level management of these functions that is currently under exclusive human control",
  - A UAMA "could emulate human capability […] i.e. the ability to construct and employ models of its own mind as well of the minds of other agents [empathy]" *in "AI in M&S"* by Zeigler, Muzy, Yilmaz, 08.
- Project : modeling the human management of the functions devoted to the M&S framework (link with IA)
- QUESTION (epistemological and methodological) : ***What about the possible link between this project and the existing management of agent-models and simulations in social sciences ?***

Context and Aim

- Context:
  - Epistemology of M&S
  - Epistemology of Agent-directed simulation
  - Agent-based modeling (Gilbert) or Agent-based simulation (Yilmaz, Ören, Zeigler)
  - But Agent-simulation too: UAMA = Agent-simulation within Agent-based simulation ? Internal / external payoffs evaluation in Muzy?
- Aim: explain and clarify some similarities and some differences in order to help in this effort to build a UAMA

Outline

- Recall some recent epistemological concepts which have been introduced (Phan & Varenne 08) to distinguish between different epistemic uses of models and simulations in the social sciences (i.e. different kinds of management of M&S in social sciences)

- Comparatively, recall the approach and context of the FM&S (system theory)

- Note how both approaches introduce a hierarchical viewpoint

- Show precisely why the general use of the notions of “system” and “hierarchy of systems” become problematic as far as a modeling of a human management of M&S of other men and other objects in the world come into view.

Broadening the notion of simulation (1)

- A **model** : a formal construct possessing a kind of unity, formal homogeneity and simplicity. These unity, simplicity and homogeneity are chosen so as to satisfy a specific request (prediction, explanation, communication, decision, etc.).
- Concerning **simulation**, current definitions need to be generalized.
- It is often said that "<u>a simulation is a model in time</u>", a "process that mimics the (supposed to be the more) relevant characteristics of a target process", Hartmann (1996). But consider:
    - The **variety** of types of contemporary CSs.
    - Today, CSs rarely are the dynamic evolution of **a single formal model**.
    - CSs in the sciences of complex objects are most of the time CSs of complex ***systems of models***.
    - Moreover, there exist ***various kinds of CSs*** of the same model or of the same system of models.

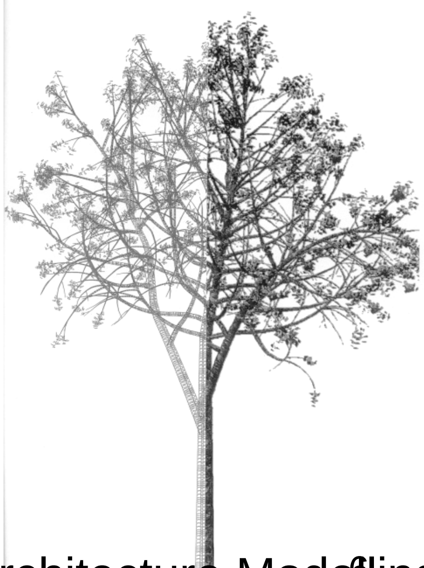
Broadening the notion of simulation (2)

- Last but not least, the criterion of the "temporal mimicry" is in crisis too: it is not always true that the dynamic aspect of the simulation imitates the temporal aspect of the target system. Some CSs can be said to be *mimetic in their results but non-mimetic in their trajectory* (Varenne, 2007) (Winsberg 2008).

- For instance, it is possible to simulate the growth of a botanical plant sequentially and branch by branch (through a non-mimetic trajectory) and not through a realistic parallelism, i.e. burgeon by burgeon (through a mimetic trajectory), and to obtain the same imitating image (Varenne 2007).

- The same remark stands for Social Sciences.
  - "Historical genesis" ≠ "logical genesis
    = the processes are not the same.

  The logical genesis progresses along an abstract / a-historic succession of steps, with no mimetic Trajectory (D. Phan).



Source : Plant Architecture Modelling Laboratory (CIRAD/France)

Broadening the notion of simulation (3)

- The problem: the temporal aspect is itself dependent on the persistent - but vague - notion of imitation or similitude.
- But, in fact, it is possible to give a minimal characterization of a CS (not a definition) referring neither to an absolute similitude (formal or material) nor to a dynamical model.
- Let's say that a simulation is minimally characterized by a strategy of symbolization taking the form of at least one step by step treatment. This step by step treatment proceeds in two major phases:
  - 1st phase (operational phase): a certain amount of operations running on symbolic entities (taken as such) which are supposed to denote either real or fictional entities, reified rules, etc.
  - 2nd phase (observational phase): an observation or a measure or any mathematical or computational re-use of the result of this amount of operations taken as given through a visualizing display or a statistical treatment or any kind of external or internal evaluations.
  - e.g., in some CSs, the simulated "data" are taken as genuine data for a model or another simulation, etc.

Iconicity in simulations

- Simulations = “iconic modeling” (Frey 1961): it was to be understood in the sense of *iconicity images can have*. I.e. simulations were seen to use the same - or similar - physical features that the ones possessed by the target system they were told to symbolize.
- Olga Fischer (1996) defines iconicity more generally as “a natural resemblance or analogy between a form of a sign […] and the object or concept it refers to in the world or rather in *our perception of the world*”. *Not all iconicities are imagic*.
- That is the reason why Fischer (1996) states that an *iconic semiotic relation* is first of all *relative to the standpoint of the observer-speaker-interpreter*.
- From these considerations, it follows what is the most important is the property of an iconic relation to be - *relatively to a given language or vision of the world* - *less dependent of this language*.
- If we follow such a post-structuralist linguistics, iconity is no more univocally defined in terms of a superficial and implausible absolute resemblance between things and signs nor by an absolute homomorphism between pre-defined and pre-structured systems (the *system* of signs, on the one hand, and the *system* of things taken in a slice of the reality, on the other).
- But *iconicity* is more largely and more fundamentally defined in terms of the property of *independence from a given language (for a relation of denotation)*

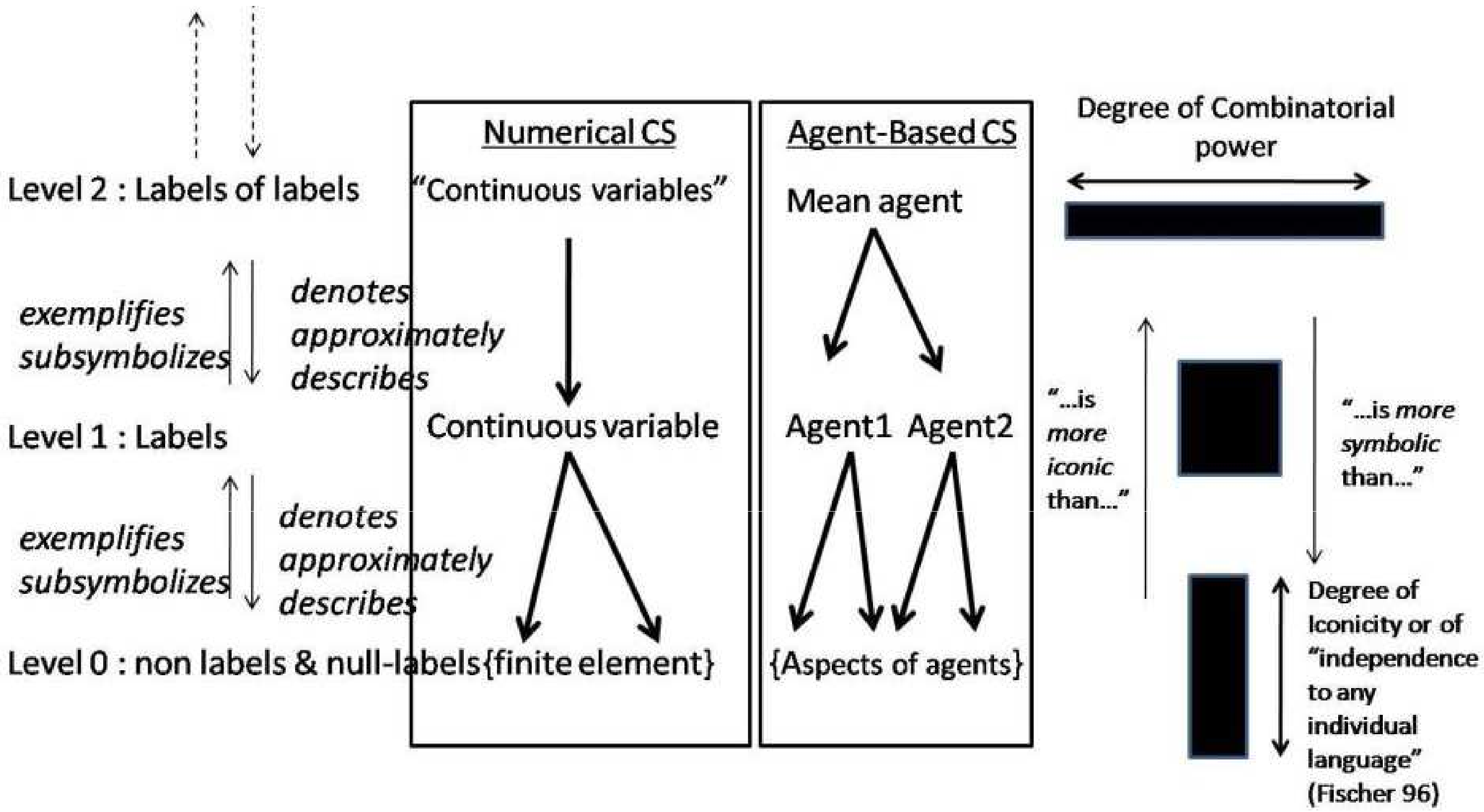
Sub-symbolhood in simulations

- Concerning the two phases in simulation (operative, observational):
  - During the observational phase, marks which were first treated as genuine symbols, i.e. as denoting entities, are finally treated as *sub-symbols*: Why? They are treated at another level at the one they first operated.
  - At the end of process, it is the result observed - as a whole - which gains a proper and new symbolic nature
  - And this is relatively to this new symbol or system of symbols that the first symbols become sub-symbols.
  - Let's recall that, according to (Smolensky 1988), subsymbols operate in a connectionist network at a lower level than the symbols. As such, they can be seen as constituents of symbols. Subsymbols "participate in numerical – not symbolic – computation": the kinds of operation on symbols (computations) are not the same at each level.

Sub-symbols, levels of symbols and hierarchy of systems

- Through that, we can see that our characterization of simulation leads us to similar considerations as the ones presented by Zeigler *et al*. (2000) (chapter 1): simulation is a question of levels of symbols.
- But, is it more precisely and always a question of levels of systems - or even of languages - strictly speaking?
- My suggestion can be now a little more substantiated and anticipated:
  - Characterizing a simulation as a relation between levels of systems is perhaps a particular – restrictive - case of characterizing it more largely as a relation between levels of symbols through a given step by step treatment.
  - In the former case (levels of systems), we have exact or approximate emulation in view (where emulation is defined as a particular case of simulation: a “perfect simulation”).
  - In the latter (levels of symbols), we have the more general case of simulation in view.

Simulations and denotational hierarchies



We can draw a parallel between the hierarchy of levels of symbols in a Goodman's hierarchy and the similar hierarchies in numerical simulations and in agent-based simulations. The relation of subsymbolization can be interpreted in terms of an exemplification whereas the relation of denotation can be interpreted in terms of an approximate description.

Simulations of Models

- From what has been said, one can explain why the term simulation can have different meanings in the technical literature. According to (Ören 2005) & (Yilmaz *et al*. 2006), for instance, **“simulation has two different meanings: (a) imitation and (b) goal-directed experimentation with dynamic models”.**
- The previous conceptual analyses confirm and explain further this matter of fact:
  - <u>First.</u> We are right to say that a computer simulation is a “simulation of a model” when its specific strategy of subsymbolization essentially is taken as a strategy of *subsymbolizing* the dynamic of the model.
    - From this viewpoint, a lapse of time taken in the dynamic of the model is *iconically denoted* by a lapse of time of computation in the CS. An iconic semiotic relation takes place here because *a lapse of time is denoted through another lapse of time*.
    - This iconic relation is not an “imitation” of a property of a target system but an imitation of an aspect of the time-consuming dynamic of the model by a time-consuming activity: a computation.
    - This hidden imitation is what permits to characterize the second meaning of “simulation” - according to (Yilmaz *et al*. 2006) - as a kind of *experimentation* (on a model or system of models).

Simulations of Target Systems

- Second. A CS can be called a simulation for another reason:
  - It can be seen as *a direct simulation of an external target system* and not as a simulation of model.
  - Here, we find what (Yilmaz *et al.* 2006) call the first meaning of simulation: *imitation*.
  - In this case, it is implicitly assumed that symbols at stake in the simulations are entering in some direct iconic relations to some external properties of the external target objects.
  - From this viewpoint, contrary to what prevails in the last case, external relations between symbols and target entities or target symbols or labels have to be taken into account.

Some applications of our epistemological concepts
1. Models as experiment

- **To what extent models can be seen as some kind of experiment?**

- E.g.: Schelling's model has an empirical dimension because some causal factors are denoted through symbols of which partial iconicity is patent and can be reasonably recognized as a sufficiently "realistic" conjecture in the argumentative approach of the domain specialist (link with the "non accidental complexity" of Hans)

- On the contrary, models are seen from an instrumentalist standpoint when the level of iconicity of their symbols is weak (the remoteness of reference is important) and when this is their combinatorial power at a high level in the denotational hierarchy which is requested (e.g. Friedman's unrealism).

- In this concern, the notion of "stylized fact" is ambiguous because it serves to emphasize either the stylization or the factuality, i.e. the iconicity of the symbolization. Independently of an explicit commitment toward a denotational hierarchy, models of "stylized facts" cannot be said a priori to be "conceptual exploration" or "experiments".

Some applications of our epistemological concepts
2- CS as experiment ON a model

- **How and why can a CS be seen as an experiment on a model?**
- Because of the analogy between any subsymbolization (such as any change of level in the DH) and the canonic relations between the formal and the material stuffs in the empirical sciences, a CS can be said to be an experiment on the model or on the system of models
- But if we focus on some residual symbolic aspects of the subsymbols at stake, we can speak of such a CS of model as a conceptual exploration. And it is because we put the stress on the residual combinatorial /symbolic power of the subsymbols that we see such a CS as a delegation of an intellectual /conceptual practice.
- It follows that external validity is a matter of degree and depends on the strength of the alleged iconic aspects. If this iconic aspect is extremely stabilized and characterized, the simulation can even be compared to an exemplification. In this case, external validity is not far from an internal one.

Some applications of our epistemological concepts
3 - CS as experiment in itself

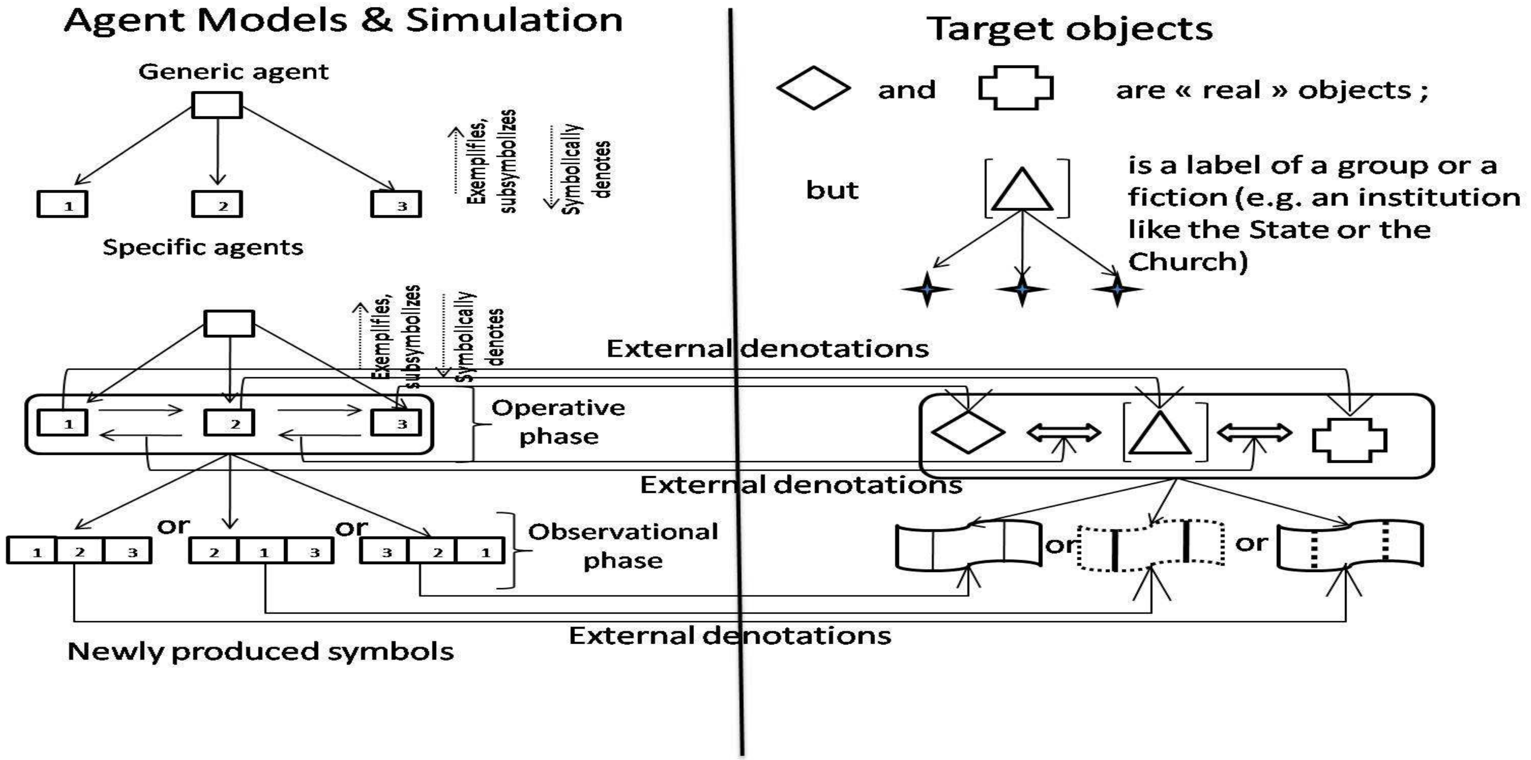
- **To what extent a CS can be seen as an experiment in itself?**

- A CS can first lend its empiricity from an experiencing, that is, from a comparison with the target (external validity): and those are (1) the empiricity regarding the causes (of the computation) and (2) the empiricity regarding the effects (of the computation).

- But its empiricity can be decided not from an experiencing but from an experimenting on the interaction between levels of symbols, i.e. between controlled and uncontrolled changing factors: and here are (1) the empiricity regarding the intrication of the denotational routes, and (2) the empiricity regarding the defect of any a priori epistemic status.

- Through this particular experimenting dimension, **software-based CS** gain some particular kind of empiricity which gives them a similar **epistemic power** than ordinary experiments.

Internal & External denotations (1)



-The iconicity of the symbol "cross" is decided in regard to *any* or to a great number of languages or systems of symbols: it can be said to be an *absolute iconicity*. This is a great difference with the *internal iconicity* we presented first, which serves to characterize any simulation and which always remains relative to a given level of symbols or language

- The latter takes place in the relations of simulation within a denotational hierarchy of levels of symbols, whereas the former denotes symbols or entities which may but have not to belong to any explicit denotational hierarchy.

Internal & External denotations (2)

- Externally denoted entities (or symbols) themselves have not to belong to any hierarchy (nor to the same hierarchy as the one of the simulation) to be denoted from a system of symbols belonging to a model & simulation-oriented denotational hierarchy.
- As a consequence, neither simple matching nor direct parallelism between the M&S-oriented DH and any real (or consensual) hierarchy relevant for the target objects is necessary.
- Another way to coin this is to say that it is not necessary for the denotated target objects to form a *system* to be simulated in a complex CS

System theory and Framework for M&S

- From the standpoint of the theory of systems, the process of modeling and simulation can be interpreted in terms of relations not only between symbols and groups of target entities, nor even between levels of symbols, but always between *levels of system specifications.*

- As a consequence, the system of target objects (more briefly the *target system*) - or *observation frame* - is situated in an integrated *system-denotational hierarchy*. It takes place at the level 0 of this hierarchy.

Simulation according to the system-theoretic view

- From the viewpoint of system theory, simulation remains fundamentally an explicitation of mathematical structures due in particular to:
  - *1st the condition of closure under composition,*
  - *2nd the strong hypothesis of the existence of a unique and comprehensive denotational hierarchy.*
- Hence, simulation is essentially interpreted as a calculus of a model.
- Consequently, it is only the model (at a higher level) which is always considered as possessing a higher degree *of informative power* in that it possesses a *higher - because a larger - power of possible denotation* through the supposedly unique *denotational hierarchy* (to which the target objects are all said to belong, at the source system level, in a well-suited systemic form).

Agents and the FM&SA (1)

- As shown by (Zeigler *et al*. 2008), the notion of endomorphic agent is central to the search for a first formulation of a UAMA.
- But, what are agents?
- As noted by (Yilmaz *et al*. 2006):
  - *“Software agents are entities that (a) are capable of acting in purely software and/or mixed hardware/software environments, (b) can communicate directly with other agents, (c) are driven by a set of goals, objectives, and tendencies, (d) possess skills to offer services, (e) perceive their environment, and (f) can generate autonomous behavior that tends toward satisfying its objectives (Ferber 1999)”*

Agents and the FM&SA (2)

- What is called Agent-based Modeling in the computational social sciences (Gilbert 2006) is quite the same as what is called Agent-simulation in the modelers and computer scientists' community.
- According to (Yilmaz *et al.* 2006), Agent-based modeling or Agent-simulation can be defined as "the use of agents as design metaphors in developing simulation models". In this context, it is assumed that "simulation models" are specifically devoted to simulations understood as *imitations of target systems*. So beware that the meaning on this expression is not based on the general meaning of "simulation" but only on its first meaning (according to Ören and Yilmaz).
- Whereas "Agent-based modeling" or "Agent-simulation" is devoted to an imitative role of simulations, what Levent Yilmaz *et al.* call "Agent-based simulation" refers - on the contrary - to the instrumental role of agents formalisms: "Agent-based simulation is the use of agent technology to generate model behavior or to monitor generation of model behavior" (Yilmaz *et al;* 2006).
- In this case, the term simulation changes its meaning: it is no more to be understood as an imitation of a target system but as "a behavior of a model", as a "model in time" or as an "experimentation on a model". We can explain this distortion by saying that, in such simulations, the emphasis is on the *internal iconic relations* and not on *the external ones*.

Agents and the FM&SA (3)

- **Now, what is an endomorphic agent?**
- An endomorphic agent is a particular agent “that contains models of itself and/or of other endomorphic agents” (Zeigler *et al*. 2008).
- When we search for a UAMA, we aim at formulating “models of mind” which could be incorporated in agents so that these agents could be said to *emulate* some of the human cognitive capacities (*ibid*.).
- In particular, the theory of the massive modularity of mind (Carruthers 2006) quoted by Zeigler - because offering the hope that an easy modeling of a multiplicity of simple modules in mind will soon be reachable - could be a way to give a first outline of a UAMA.

Agents and the FM&SA (4)

- The universal autonomous modeler agent and the "modeler subjective knowledge" (Klir 85)

- Thanks to the previous conceptual distinctions, we see that the conception of a universal endomorphic agent, which would construct by himself - at runtime - a theory of his mind-body, is a way for the FMSA to *guarantee the continuous integration* of the target objects in a *unique denotational hierarchy*, during the whole process of M&S.
- In fact, the system theoretic vision, together with the constraints of strict embedding between levels of symbols and the condition of closure under composition of systems authorize to take into account and integrate in the hierarchy of system specifications what Klir nevertheless rejected and called the "subjective (or modeler dependent) knowledge".
- This is the reason why it is justified to see a real challenge in this new project.

Conclusions (1)

- The relations between *the levels of symbols within the DH* and the relations between *symbols of the DH and some target objects or target symbols* (these latter being based on the modeler dependent knowledge) are *not* of the same nature
- The former are supposed to give rise to *relative internal iconicities* whereas the latter can give rise to *absolute external iconicities*. So, the meanings and extensions of these two types of semiotic relations are *not the same*.
- If we neglect this difference, the diversity of the epistemological positions concerning the epistemic statuses of models and simulations among the different practices of M&S in empirical (social, behavioral…) sciences remains unexplainable.

Conclusions (2)

- So, one of the greatest challenges for the search for a UAMA could be the careful formulation of this *distinction of nature between* symbols and between relations between symbols and target objects for any modeled cognitive process.

- If we want to implement endomorphic agents who would be automated modelling and simulating agents, contrary to what happens in Agent-Based modeling in social sciences, there will be no possibility to defer ultimately to a *subjective viewpoint* of the modeller, and there will be a necessity to formalize in some way this *external relation of denotation.*