Conclusion

Currently, the art of creation of models benefits from tools coming from well established scientific disciplines. Some of these disciplines focus on the laws of life (e.g., Biology and Ecology), others focus on the laws of matter (e.g., Physics and Geology), some on the laws of societies (e.g., Sociology and Economics), others on the laws of human cognition (e.g., Artificial Intelligence and Psychology.) All these disciplines try, autonomously, to expand the explanatory boundaries of their models through simulation. At the same time, some computer scientists collaborate with specialists from different disciplines to confront and improve their own tools. What emerges from this current evolution is that computation-based Modeling & Simulation is today facing the challenge to improve modeling tools, toward increased multiphysical, multiformalism, multiperspective, multiscaled and/or integrated models. From this viewpoint, it clearly appears that there is a common need for more sophisticated and integrating modeling tools.

What should these tools be? First, they have to be abstract enough to become domain-specific. A well accepted common structure is the general system inherited from systems theory. The mathematical description (developed by Mesarovic, Klir, and Wymore) of the general system has proved to be worthy of specification through Zeigler's discrete-event systems. These computational systems are really the fundamental materials for the construction of computational models. However, if the discrete-event system specifications are the cells to build the organs, new plans and knowledge have to tell modelers how to connect these cells, how these cells can interact in an autonomous efficient way to constitute an organ, and how these organs can interact to constitute a body.

Systems are increasingly fine-grained and miniaturized. Hardware is perpetually improving its efficiency. Grids, distributed and parallel simulations are more and more massive. Disciplines use these interacting distributed systems, through more and more individual-based models and interacting parts of codes. However, tools are rare for the study of simulation results[1] and there is little information about how to link: existing powerful discipline models (e.g., statistical physics and Entropy, or Operational research and optimization tools) and generative systems. Moreover, although multi-agent systems contributed to the emergence of new locally interacting control mechanisms, to achieve a common goal, a broader framework embedding both autonomous and automatic control of systems needs to be developed. What should these new structures be? From which other structures can they be inspired?

It can be accepted that whatever our models of Reality, it will be difficult to discover the true nature of the laws of Reality. Hence, we can follow Hume, for instance, when he claims that every idea comes from empirical reality, through a process of abstraction. More than empiricism, the necessary shift from artificial intelligence to artificial life tells us that we now need to take into account, both the laws of life and the laws of matter simultaneously, to be able to manipulate and understand them. Therefore, models need to be more and more related to, inspired from, based on, and compared to Reality. This sounds like euphemism. However, precisely, our efforts should be concentrated on the forms, mechanisms, algorithms translating reality into models.

But which mechanisms characterize the physical and natural laws of Reality?

Here, are certainly some:

- Causality and contingency of events in time and space,
- Action and reaction (which relates to causality),
- There is no free lunch ;-): Every action has a cost and a possible benefit. Every physical and chemical reaction consumes and produces energy. For any one action, a trade-off exists between the matter (to be) consumed and the energy (to be) produced, the cost and the benefit of this action. - For sustainability, fidelity and efficiency, there exists an optimal allocation of resources between usages and resource availability within the simulation to reach its goal.

1. Simulators generate massive data through massive process interactions. Operational tools need to be developed to deal with the spatiality, the interactions, the correlations, as well as the pertinence of these data. The hidden meaning behind these data (to enhance our knowledge of the model) needs to be revealed.

At the beginning of this new numerical century, the challenge of the theory of modeling and simulation will definitely be to try integrating knowledge of all scientific disciplines to be more successful than the physico-mathematicians of the past century (such as Rashevsky or Rosen) in abstracting the main physical and natural mechanisms of Reality, integrating knowledge of all scientific disciplines. What a challenge!

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