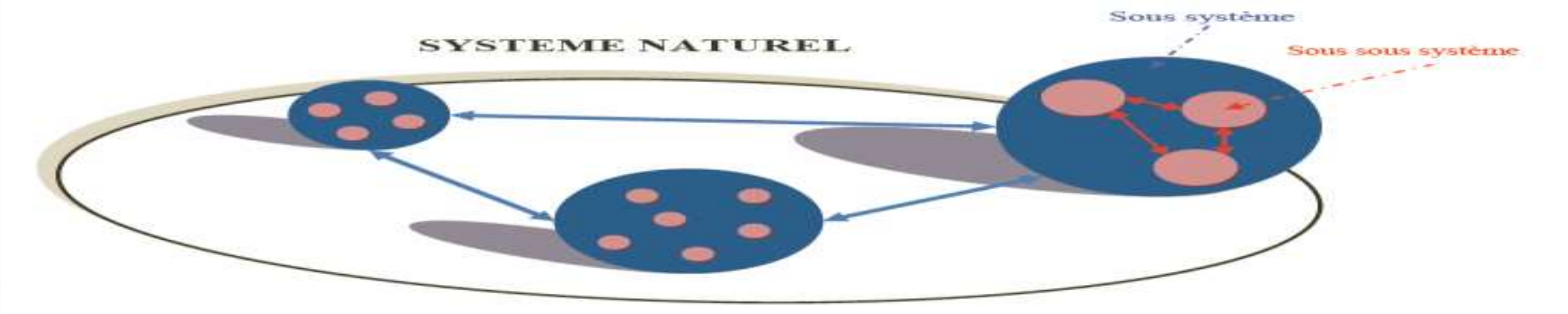
University of Msila
FACULTY OF MATHEMATICS AND INFORMATICS
DEPARTMENT OF COMPUTER SCIENCE

Modelling and simulation (Introduction)

Concept of System

- A system corresponds to a set of elements in interaction,
  - organized according to a specific purpose.
  - These elements operate within a set of environments and form a whole;
  - each part has well-defined functions to fulfill and a certain degree of autonomy.
  - This ensemble interacts over time; it exists within an environment that exerts influences on it and upon which it can act.
  - The purpose of this ensemble is, therefore, to produce specific functions for which it was created.
  - Each element of the system (which can itself be a subsystem or even a system) has a well-defined role to play.

Concept of System



- **Categories of Systems**
- **Natural Systems:** These systems are used to describe natural phenomena and their properties. Examples include the molecular system, the cellular system, the nervous system, the immune system, the cloud system, and the solar system.
- **Artificial Systems**: In this case, systems are used to describe concepts created by human activity in various domains.
- In Information Technology and Telecommunications: The computer system, the expert system, the telecommunications system, the control system.

Complexity of Systems

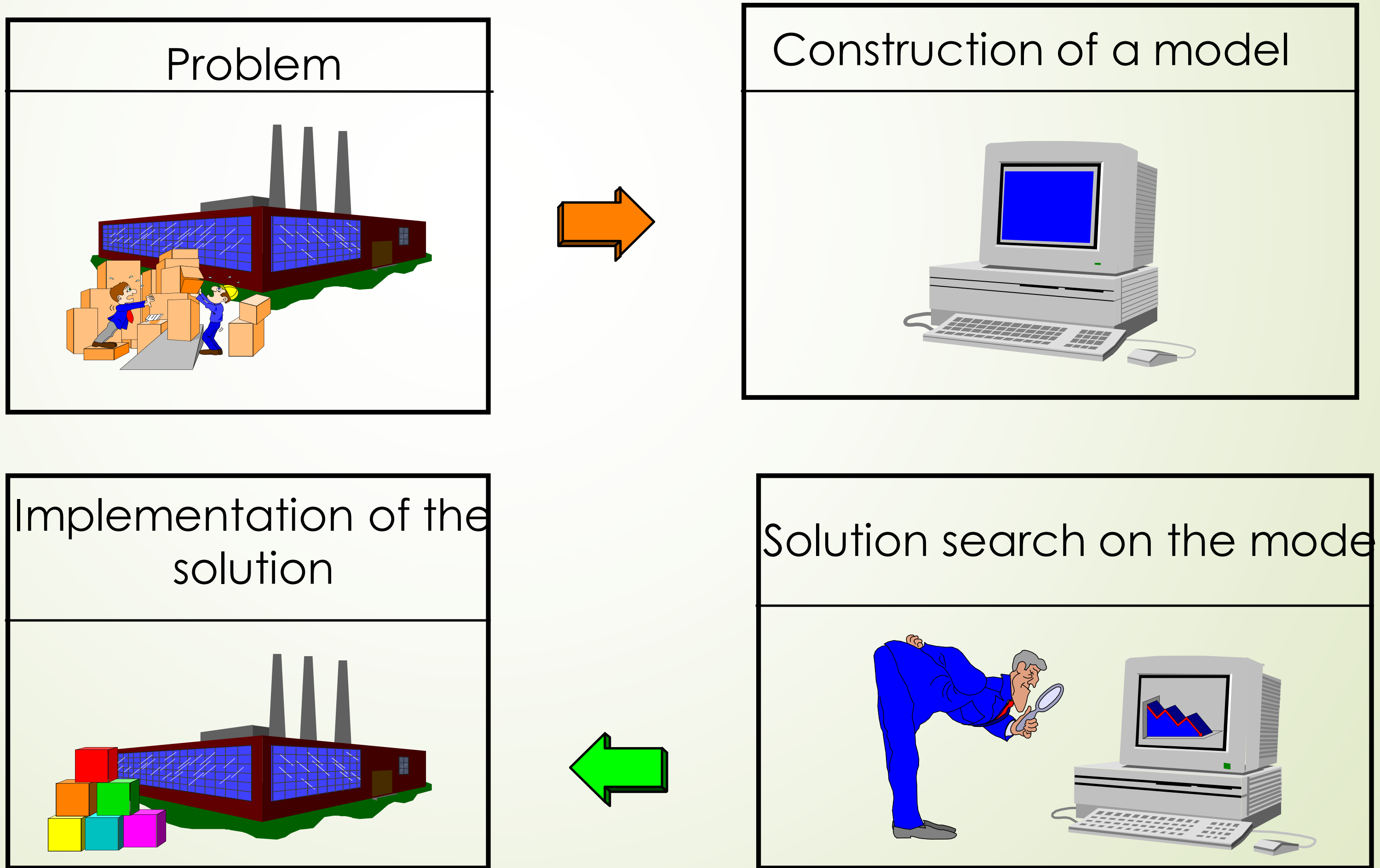
- A complex system is a system composed of numerous elements that interact strongly with each other and with their environment.
- These interactions are often non-linear and typically involve feedback loops.
- These systems are characterized by the emergence of phenomena that are not observable at the level of their constituent elements: an external observer will perceive and understand the system differently from an observer internal to the system. Therefore, it is characterized by the emergence, at the global level, of new properties and a global operational dynamic that is difficult to predict based solely on the observation and analysis of elementary interactions.

Real and Virtual Systems

- With the advent of computing, the possibility to construct simulations of "real" complex systems has developed, and these simulations themselves become "virtual" complex systems.
- The computer techniques used in this field, including those of artificial life, encompass various techniques and methods such as genetic algorithms, object-based modeling, multi-agent systems, etc.,
- giving them a somewhat unique status. They serve as both modeling tools for studying systems, whether biological, economic, industrial, or others, and objects of study in themselves, enabling an improved understanding of certain properties of these systems.

Simulation

- For an observer A, b is a model of B if A can learn, from b, something useful about the functioning of B.



System modeling

- The objective of modeling, in its most general sense, is the understanding of the real world.

Both the so-called hard sciences (physics, chemistry, biology, ...) and the social sciences (economics, sociology, psychology, ...) propose models.

- These models are initially validated through the comparison of their results with those of feasible experiments.
- Once validated, they have predictive value and suggest other experiments that have not been conducted before.
- If these new experiments corroborate the model's predictions, then its validation is confirmed, and the understanding of the modeled domain is truly enhanced."

System modeling

- **Model**: A model is a simplified representation of reality that helps us understand the functioning of a system in response to a question.
- Every model consists of a description of the system's structure, incorporating integrated semantic specifications, and a description of regular (or irregular) functions and dynamics that modify this structure over time.
- The objective of modeling is to gain knowledge of the real world.

System modeling

- **Types of Models:** Several types of models are distinguished based on the nature of the studied system.

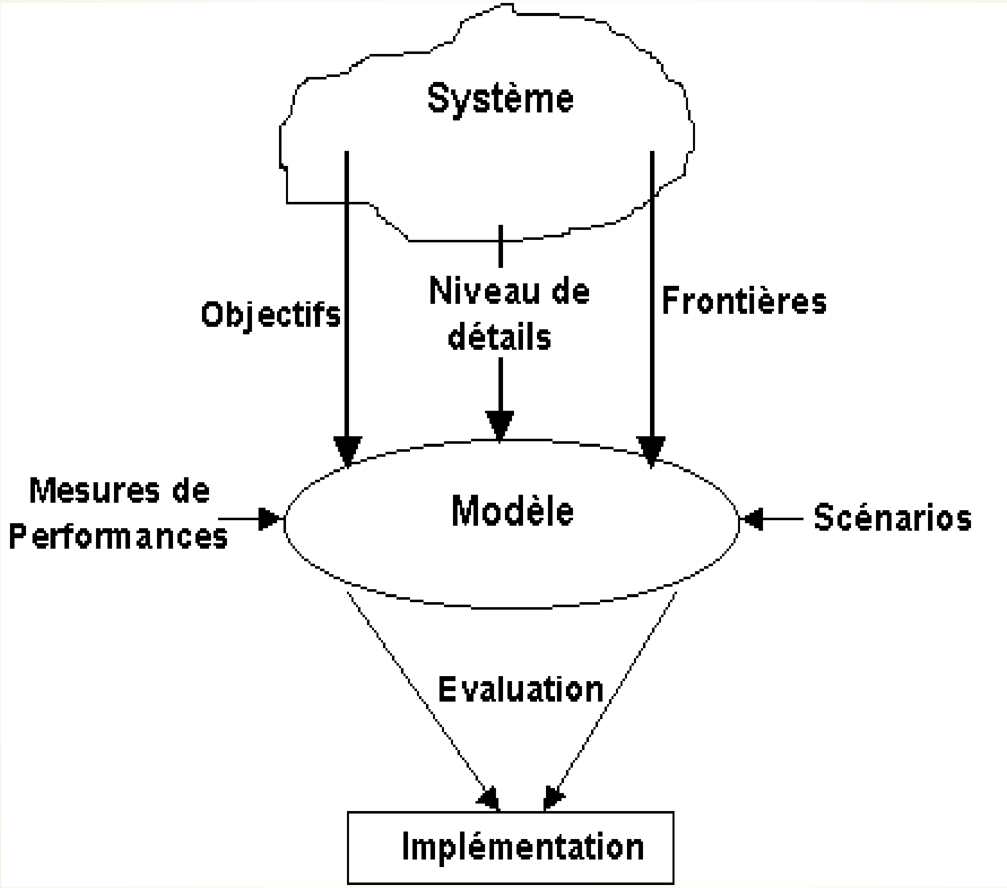
1. **Deterministic Model:** This model is based on the development of precise equations, and the system is entirely predictable.
2. **Stochastic Model:** This model introduces random phenomena, accounting for the 'randomness' commonly found in ecosystems.
3. **Simulation Model:** It generally has the advantage of avoiding complex mathematical modeling and allows the representation of environments with a large number of actors exhibiting different behaviors. It represents the model immersed in time.
4. **Physical Model:** A physical model is a replica of reality; reduced models are still widely used, especially due to their ability to account for complex boundary conditions and their materiality, which often appeals to project owners.
5. **Mathematical Model**: The mathematical model is a translation of reality to apply mathematical tools, techniques, and theories to it. This model consists of equations, themselves composed of variables.
6. **Computer Model**: In this model, reality is represented by a set of computer programs that, when executed, describe the evolution of the variation of a set of variables over time. The computer model is currently the most widely used. In some complex systems, such as in the construction of airplanes or automobiles, prototypes of the real system are generally used, on which computer simulations are performed."

System modeling

- **Computer Modeling Tools**:

1. **Entity/Relationship Model**: The Entity/Relationship model was proposed for data modeling and the relationships that exist between them, using simple and effective concepts. It is built around three concepts: Entity, Association, and Properties, allowing for a graphical description.
2. **Relational Model**: The relational model allows for a tabular description of data, meaning that data is structured into tables (relations). Additionally, relational algebra enables the manipulation of this data based on set theory. The MERISE analysis method relies on the combination of the entity/relationship and relational model concepts.
3. **Object-Oriented Model**: The object-oriented model considers the system as a collection of distinct, identified objects with characteristics
4. **Agent-Oriented Model**: The agent-oriented approach provides a much more natural way to design systems. It focuses on how to divide a problem into a set of distributed and cooperating entities and how to share knowledge of the problem to obtain a solution. This field initially emerged to solve problems in distributed intelligence (IAD)

System modeling

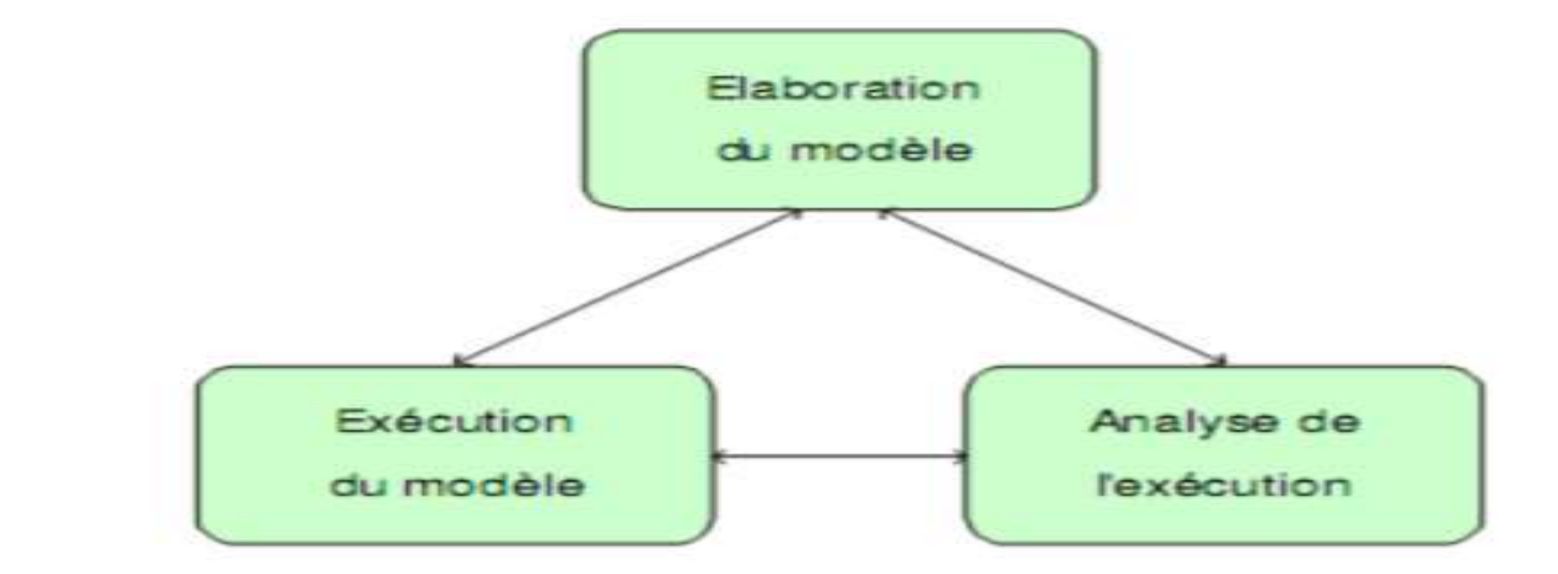


System Simulation

- The modeling and simulation of complex systems constitute a major challenge in various domains of human society today. They enable testing hypotheses, transmitting them, presenting them, and formulating new ones afterward.
- This tool thus represents a unique means of investigation for scientists, regardless of the considered domain
- Simulation is a decision support tool widely used by designers and managers of complex systems. It involves constructing a model of a real system (physical, economic, human, etc.) and conducting experiments on this model to understand the behavior of the system and improve its performance.
- **Examples of application areas include**:
  - Meteorology: It helps in avoiding natural disasters.
  - Medicine: Surgery, pharmaceuticals, etc.
  - Industry: Computer-aided design of automobiles, flight simulators, etc.
  - Video games.
  - Astronautics (space navigation): Simulating life in a space shuttle."

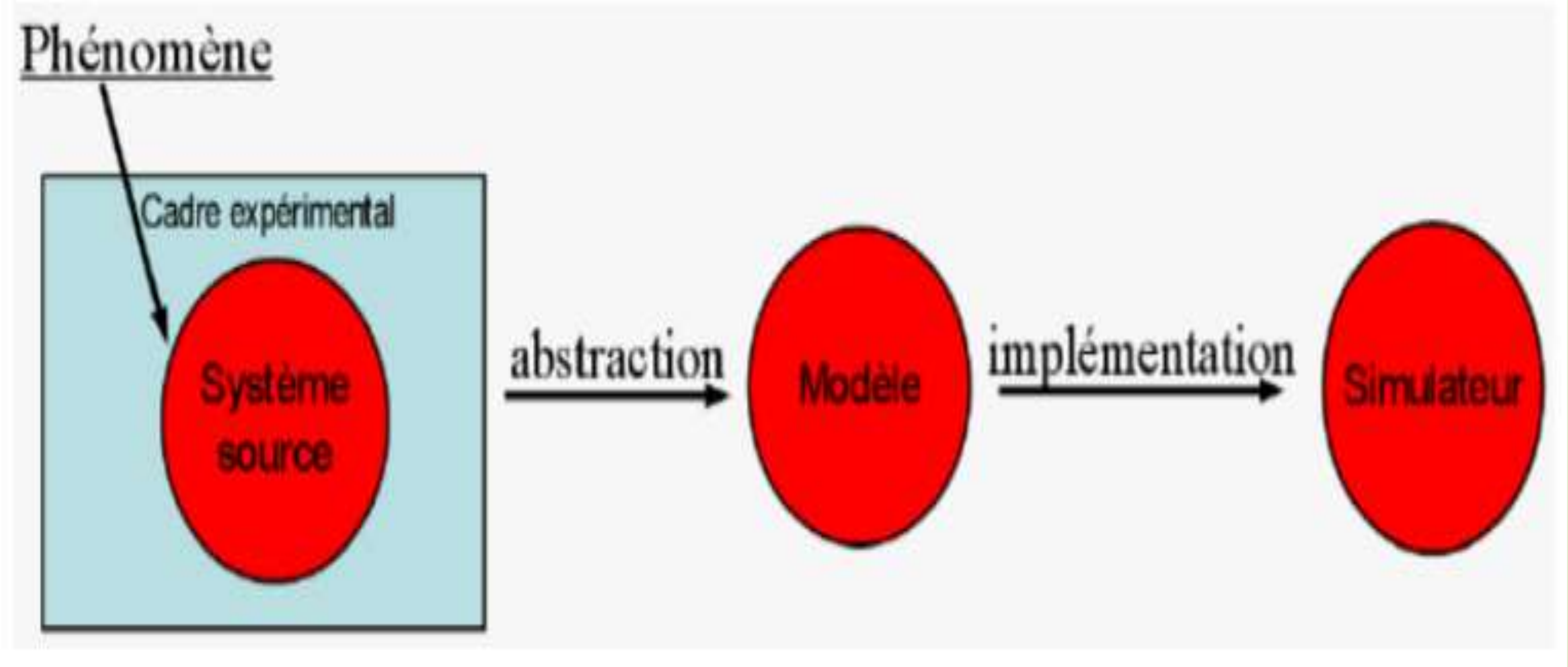
System Simulation

- Computer simulation is the discipline that involves designing a model of a real or theoretical system, executing this model on a computer, and analyzing the outputs to draw necessary conclusions.
- Simulation can be characterized by the following keywords:
  - A fundamental element, which is the model.
  - The model is manipulated (on a computer), and the solutions obtained are those of the model, not the modeled system.
  - Its goal is to choose, among the solutions, the one that appears to be the best



System Simulation

- Computer science allows for the simulation of real-world phenomena on a computer. The main purpose of computer simulation is:
- To study a real system in order to understand its internal functioning and/or predict its evolution under certain conditions.
- To design a computer model that is a faithful representation of the real system and is used to conduct experiments



System Simulation

Types of simulation:

1.Continuous Simulation: In this type of simulation, the system is represented by a set of differential equations to solve. It serves as a substitute for analytical resolution when it is not feasible. Initially performed on analog computers, it has also been carried out on digital computers.

2.Discrete Simulation: In discrete simulation, the system undergoes a series of events that modify it. The system is characterized by events that occur at non-fixed intervals and lead to changes in the system's state. The system retains this state until the next event.

Example: Arrival of a customer at a post office counter. If the employee is available, the customer will be served immediately; otherwise, the customer joins a waiting queue.

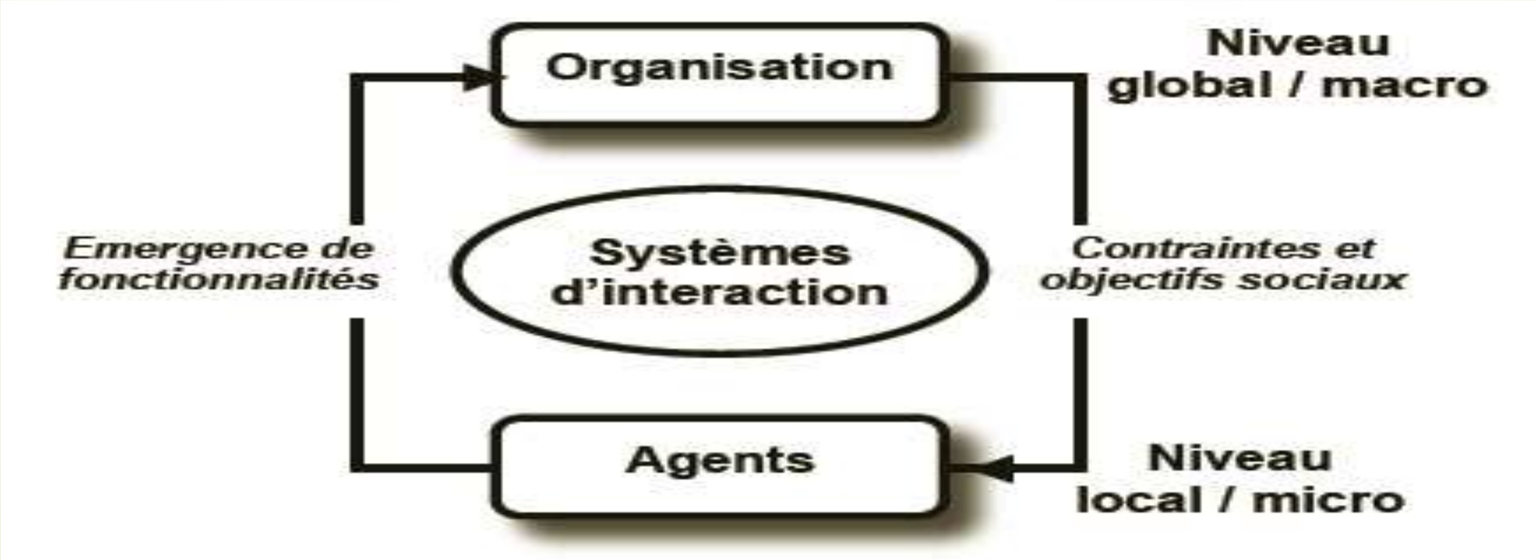
The system's state changes with each customer arrival and departure event.

3.Object-oriented simulation: This type of simulation is based on the concept of objects and object classes. Notions associated with this kind of concept, such as encapsulation and inheritance, are utilized to model and simulate applications. The Unified Modeling Language (UML) is based on this principle, and several powerful programming languages such as DELPHI and JAVA incorporate these concepts.

4.Agent-based simulation: In agent-based simulation, the simulation is divided into different entities that interact with each other. It is now used in practically every field, although initially, it was primarily associated with economic and social domains, where each agent represents an individual or a group of individuals. By nature, its operation is asynchronous.

System Simulation

- Emergence refers to the presence of emergent properties when a system, taken as a whole, exhibits behaviors that are not explicitly present in each of its components. These behaviors result from the internal dynamics of the system and/or its dynamic interactions with the environment. It is also possible to interpret this kind of phenomenon as a coupling between interacting components (local or micro-level) and the overall organization of the system (global or macro-level).



System Simulation