Introduction to Systems

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Modeling and Simulation

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Introduction

The term *System*

The term system is derived from the Greek word *systema*, which means an organized relationship among functioning units or components. It is used to describe almost any orderly arrangement of ideas or construct.

According to the Webster International Dictionary, a system is an **aggregation or assemblage of objects united by some form of regular interaction or interdependence**; a group of diverse units so combined by nature or art as to form an integral; whole and to function, operate, or move in unison and often in obedience to some form of control. ’

Introduction

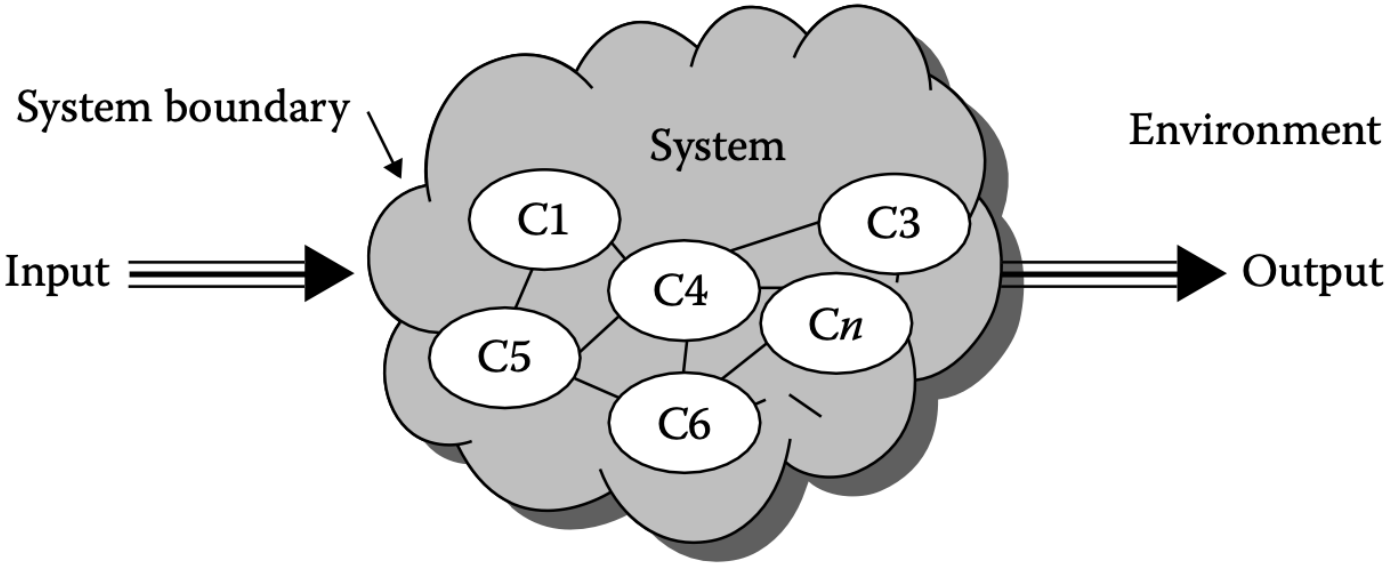


Figure 1: System as collection of interconnected components

Introduction

Some examples of the systems

- Biological / medical systems.
- Socioeconomic systems.
- Communication and information systems.
- Planning systems.
- Solar systems.
- Manufacturing systems.
- Transportation systems.
- Physical systems (electrical, mechanical, .. etc.).
- Management systems.

Introduction

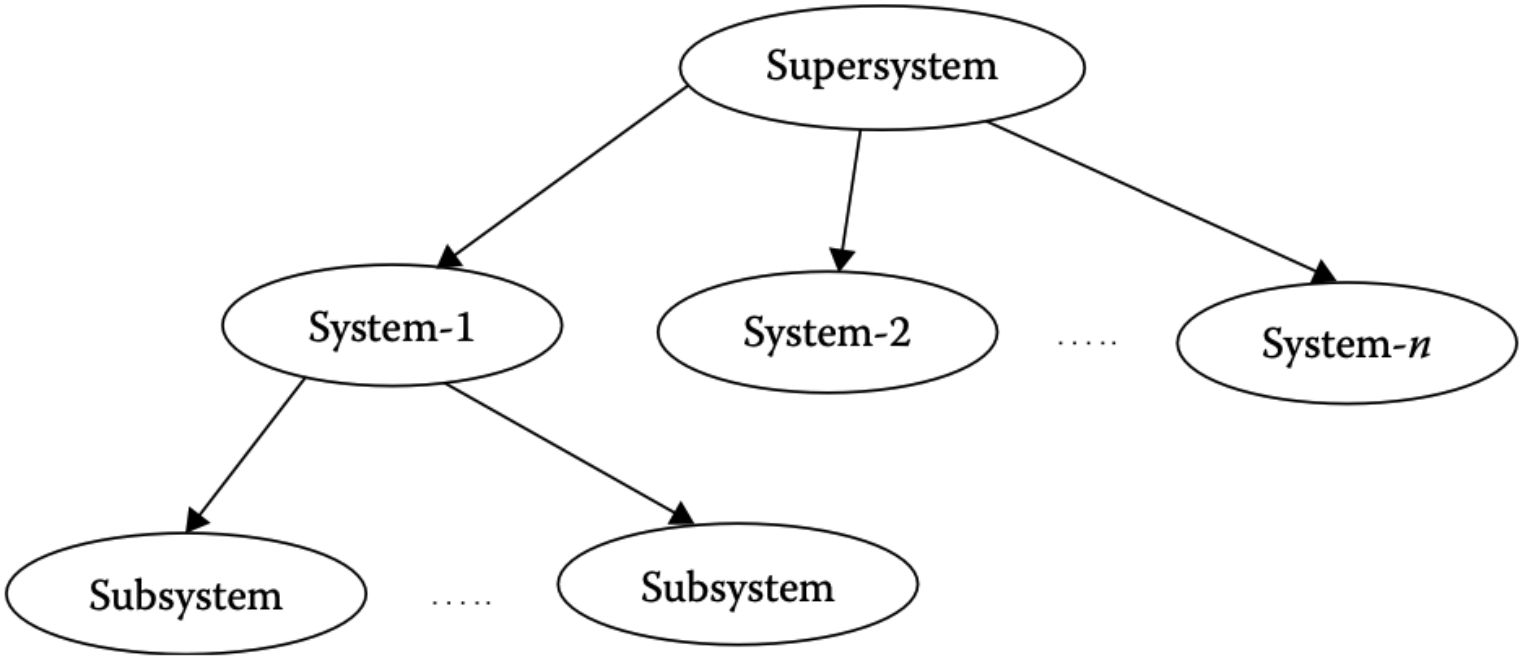


Figure 2: Hierarchically nested set of systems.

Attributes of systems

A system is characterized by the following attributes:

- System boundary.
- System components and their interactions.
- Environment.

System Boundary

To study a given system, it is necessary to determine what comprises (falls inside and what falls outside) a system. For this a demarcation is required to differentiate entities from the environment. Such a partition is called a system boundary.

System Boundary

Some points about the system boundary:

- It is a partitioning line between the environment and the system.
- System is inside the boundary and environment is outside the system.
- A real or imaginary boundary separates the system from the rest of the universe.
- System exchanges input–output from its environment.
- This boundary might be material boundary or immaterial boundary.
- System boundary may be crisp (clearly defined) or fuzzy (ill defined).

System components and their interactions

Some points about systems components:

- It is static or dynamically changing with time, input, or state of the system.
- Interaction may be constrained or nonconstrained type.
- The component interaction may be unidirectional or bidirectional.
- Interaction strength may be 0, 1, or between 0 and 1.

Environment

Example

When we model a city as a pollution production system, regardless of which chimney emitted a particular plume of smoke, it is sufficient to know the total amount of fuel that enters the city to estimate the total amount of carbon dioxide and other gases produced. The "**black box**" view of the city will be much simpler and easier to use for the calculation of overall pollution levels than the more detailed "**white box**" view, where we trace the movement of every fuel tank to every particular building in the city.

Need of System Modeling and Simulation

Models are used to mimic the behavior of systems under different operating conditions. This may also be done with the help of system experimentation. But, sometimes it is inappropriate or impossible to do experiments on real systems due to the following reasons.

Need of System Modeling and Simulation

Too expensive: Experimenting with a real system is an extremely costly affair. For example, the physical experimentation of a complex system like the satellite system is quite expensive and time consuming.

Risky: Risk involved in experimentation is another factor. In some systems there is a risk of damaging the system, or a risk of life. For example, training a person for operating the nuclear plant in a dangerous situation would be inappropriate and life threatening.

Classification of Systems

According to the time frame

- Discrete.
- Continuous.
- Hybrid.

According to the Complexity of the System

- Physical Systems.
- Conceptual Systems.
- Esoteric Systems.

Classification of Systems

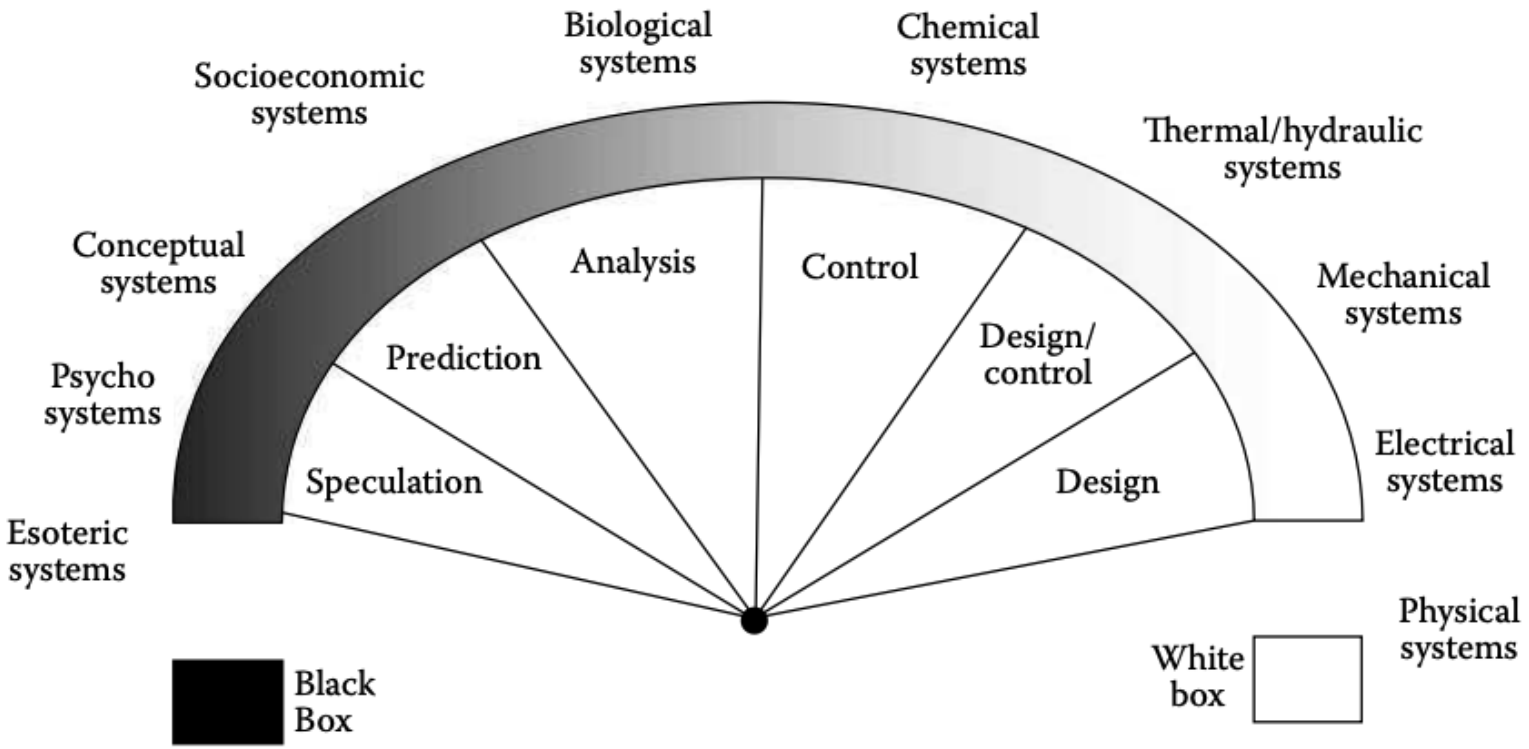


Figure 3: Classification of system based on complexity.

Classification of Systems

According to the Interactions

- *Independent*—If the events have no effect upon one another, then the system is classified as independent.
- *Cascaded*—If the effects of the events are unilateral (that is, part A affects part B, B affects C, C affects D, and not vice versa), the system is classified as cascaded.
- *Coupled*—If the events mutually affect each other, the system is classified as coupled.

Classification of Systems

According to the Nature and type components

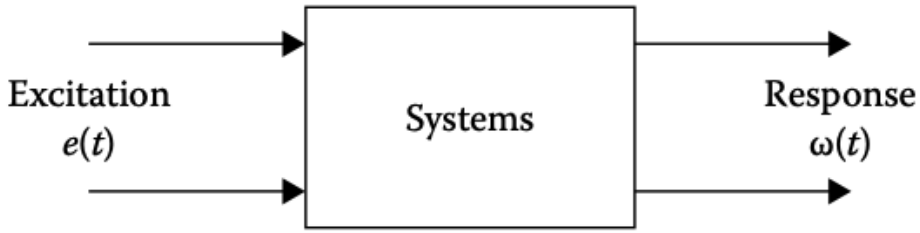
- Static or dynamic components.
- Linear or nonlinear components.
- Time-invariant or time-variant components.
- Deterministic or stochastic components.
- Lumped parametric component or distributed parametric component.
- Continuous-time and discrete-time systems.

Classification of Systems

According to the uncertainties involved

- *Deterministic* — No uncertainty in any variables, for example, model of pendulum.
- *Stochastic* — Some variables are random, for example, airplane in light with random wind gusts, mineral-processing plant with random grade ore, and phone network with random arrival times and call lengths.
- *Fuzzy systems* — The variables in such type of systems are fuzzy in nature. The fuzzy variables are quantified with linguistic terms.

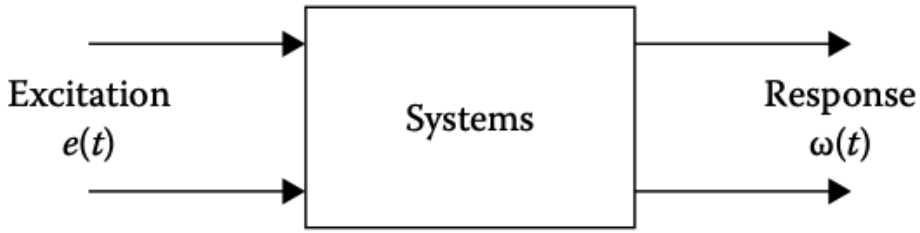
Linear vs. nonlinear systems



Superposition Theorem

$$\textit{IF}\ e_1(t) \rightarrow \omega_1(t)\ \textit{AND}\ e_2(t) \rightarrow \omega_2(t)$$
$$\textit{THEN}\ e_1(t) + e_2(t) \rightarrow \omega_1(t) + \omega_2(t) \quad (1)$$

Linear vs. nonlinear systems



Homogeneity

$$\Sigma_{k=1}^{n} = ne_1(t) \rightarrow \Sigma_{k=1}^{n}\omega_k(t) = n\omega_1(t) \tag{2}$$

Continuous-Time and Discrete-Time Systems

Systems whose inputs and outputs are defined over a continuous range of time (i.e., continuous-time signals) are continuous-time systems. On the other hand, the systems whose inputs and outputs are signals defined only at discrete instants of time $t_0, t_1, t_2, \ldots, t_k$ are called discrete systems. The digital computer is a familiar example of this type of systems.

Continuous-Time and Discrete-Time Systems

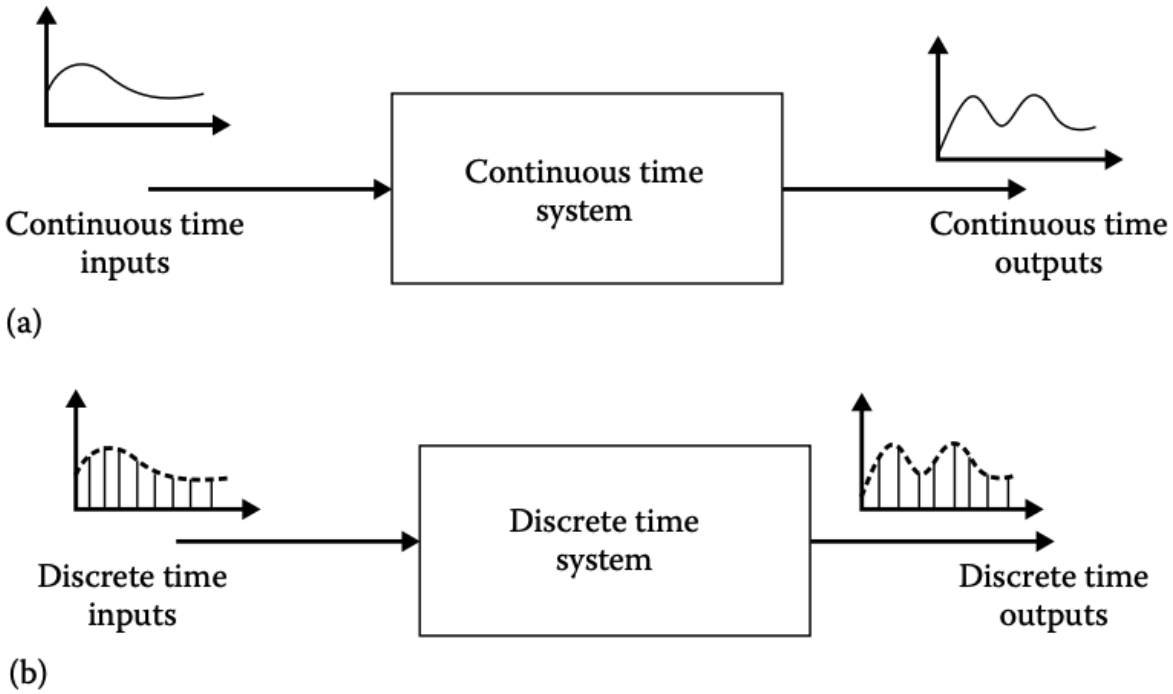


Figure 4: Continuous and Discrete Systems

Classification of Models

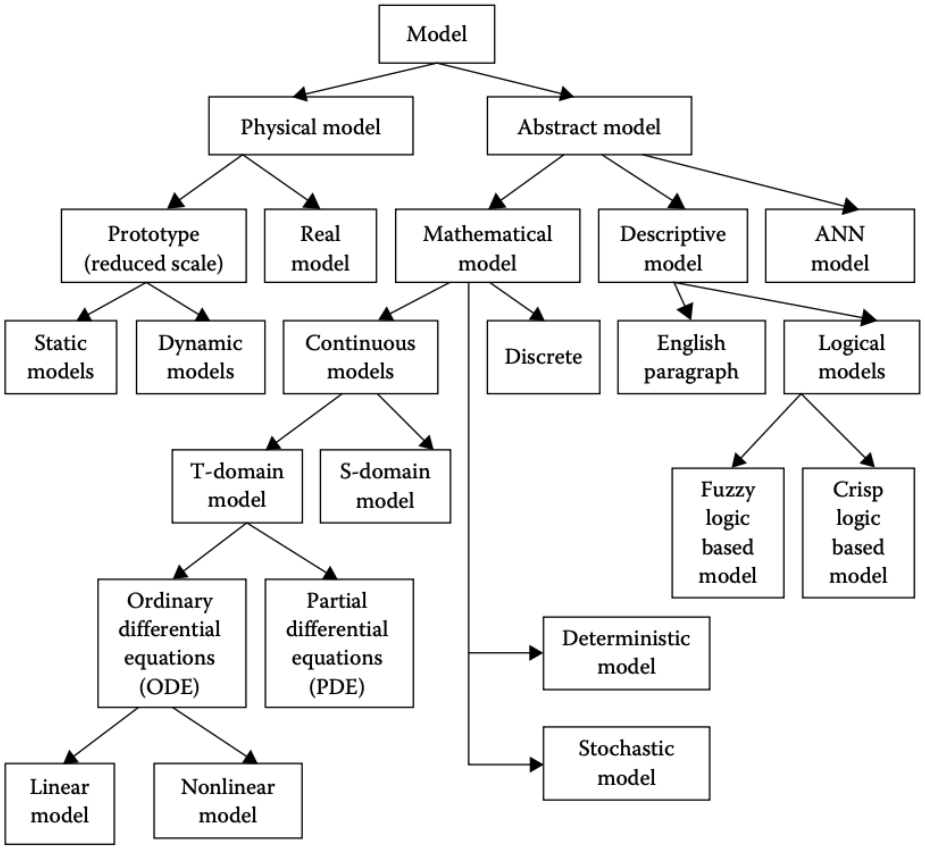


Figure 5: Classification of Models

Classification of Models

Model	Descriptive Capability	Ambiguity	Manipulation Capability	Implementation Capability	Primary Function
English text	Good	Very ambiguous	None	Limited	Descriptive explanation and directions
Drawings and block diagrams	Good	Not ambiguous	None	Good	Design, assembly and construction
Logical flow charts and decision tables	Fair	Not ambiguous	None	Good	Computer programming
Curves, tables monographs	Fair	Not ambiguous	Good	None	Express simple relations between a few variables
Mathematical	Poor	Not ambiguous	Excellent	Good	Problem solution and optimization

Figure 6: Classification of Models

Modeling process

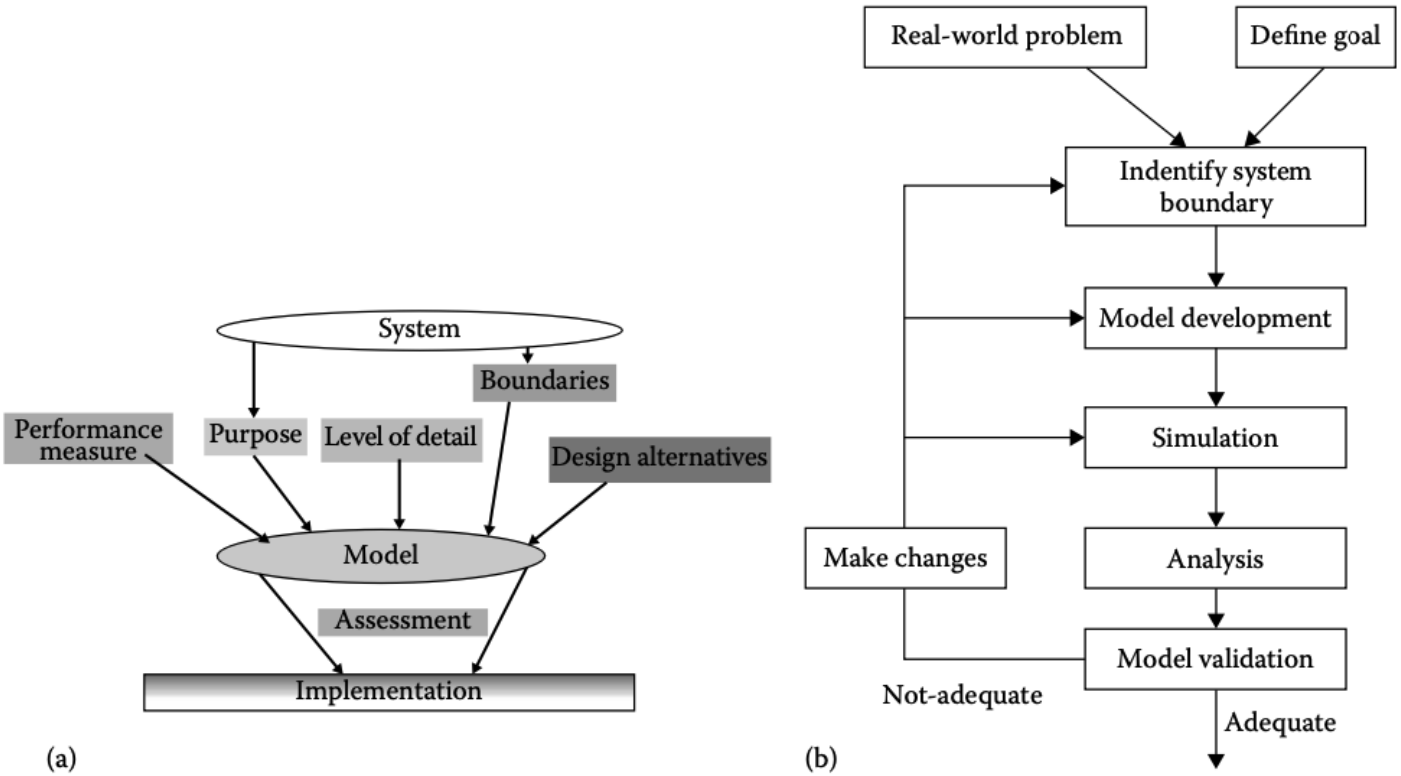


Figure 7: Modeling process

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