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Chap.2 Framework for Modeling and Simulation

Introduction

- a framework for modeling and simulation that defines *entities* and their relationships
- basic entities

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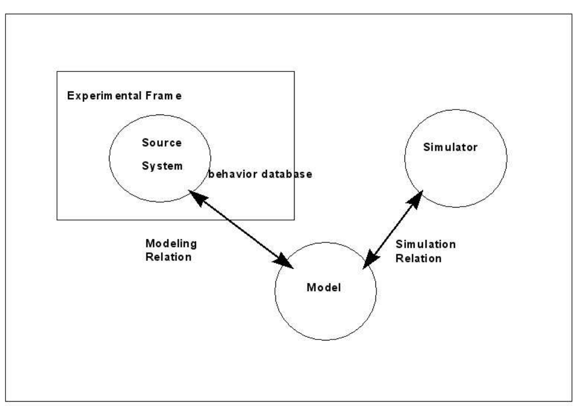

Introduction (Cont'd)

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Basic Entity	Definition	Related System Specification Levels
source system	real or artificial source of data	known at level 0
behavior database	collection of gathered data	observed at level 1
experimental frame	specifies the conditions under which system is observed or experimented with	constructed at levels 3 and 4
model	instructions for generating data	constructed at levels 3 and 4
simulator	computational device for generating behavior of the model	constructed at level 4

Entities of the framework

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- source system
  - the real or virtual environment that we are interested in modeling
  - viewed as a *source of observable data*
  - system behavior database
    * gathered from observing or experimenting with a system
    * acquired through experimental frames

Entities of the framework (Cont'd)

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- experimental frame
  - a specification of the conditions under which the system is observed or experimented with
  - operational formulation of the objectives that motivate a modeling and simulation project
  - for example
    * a forest
    * the set lightning, rain, wind, smoke represents one particular choice
    * interest in modeling the way lighting ignite a forest fire
    * refined experimental frame adds
      · the moisture of the vegetation
      · the amount of unburned material
  - two aspects
    * many experimental frames for one system: different objectives in modeling
    * an experimental frame for many systems: same objectives in modeling different systems

Entities of the framework (Cont'd)

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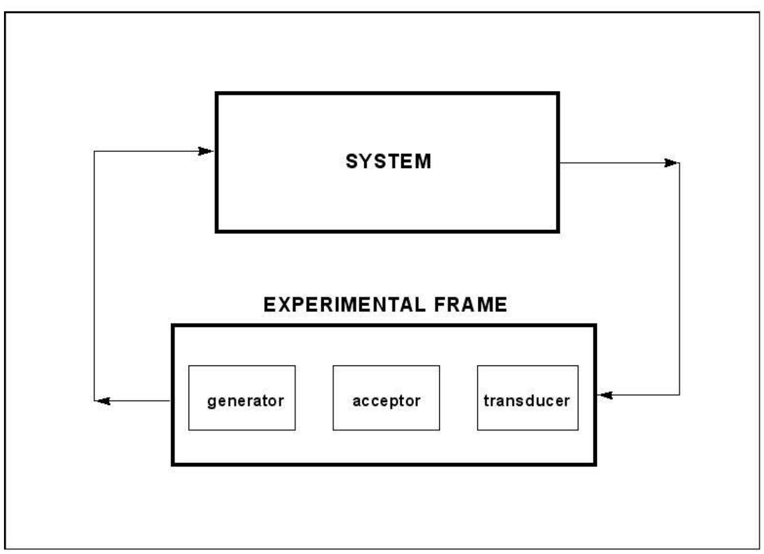
- experimental frame and its components



Entities of the framework (Cont'd)

– objectives and experimental frames
  * the process of transforming objectives into experimental frames
  * objectives →outcome measures →output variables
  * output variables →outcome measures (by transducer)

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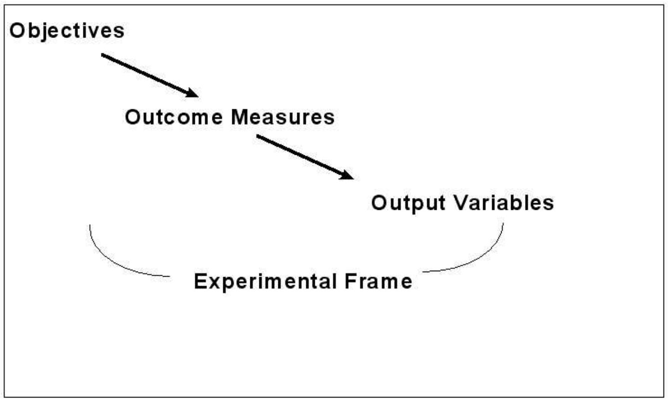

Entities of the framework (Cont'd)

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* outcome measures
  · for example, a performance measure
    the success of a missile in hitting its target
  · measures of effectiveness
    how well the overall system goals are being achieved
* for example, forest fire management

(1) fighting fires when they break out (interdiction)
  - require prediction of where the fire will spread to allocate resources
  - require highly reliable short-term predictions
  - a typical question: is it safe to put a team of the fire fighters on a particular ridge

(2) preventing fires in the first place or minimizing the damage (prevention)
  - less emphasis on short-term prediction than on answering questions for planning
  - land use planners might ask what should be the width of a fire break around a residential area

Entities of the framework (Cont'd)

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* according to objectives, experimental frames are quite different
  · interdiction
    - prevailing fuel, wind, and topographic conditions are entered
    - output desired is a detailed map of fire spread after 5 hours
  · prevention
    - a range of expected lightning, wind, rain, and temperature regimes are entered
    - output indicates whether or not the residential area was engulfed by fire
    - different fire break spatial regions might be investigated

Entities of the framework (Cont'd)

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- model
  - is a system specification
  - the most common concept
    * set of instructions
    * rules
    * equations
    * constraints for generating I/O behavior
  - make a model with
    * a state transition and output generation mechanisms (level 3) to accept input trajectories and generate output trajectories depending on its initial state setting
    * such models are used to construct more complex models by coupling them together (level 4)
  - many meanings
    * for examples, any physical, mathematical, or logical representation of a system, entity, phenomenon, or process

Entities of the framework (Cont'd)

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- simulator
  - a model
    * is a set of instructions
    * needs some agent capable of actually obeying the instructions and generating behavior
    * the agent is a simulator
  - any computation system capable of executing a model to generate its behavior
    * for example, a single processor, a processor network, the human mind, or more abstractly an algorithm
  - separating the model and simulator concepts provides a number of benefits
    * the same model may be executed by different simulators (portability and interoperability)
    * simulator algorithms may be formulated and established

Primary relations among entities

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- entities and relations
  - entities: system, experimental frame, model, simulator
  - we build a model of a particular system for some objectives
  - relations: *modeling* and *simulation*

Primary relations among entities (Cont'd)

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Basic Relationship	Definition	Related System Specification Levels
modeling relation replicative validity predictive validity structural validity	concerned with how well model-generated behavior agrees with observed system behavior	comparison is at level 1 comparison is at level 2 comparison is at level 3,4
simulation relation correctness	concerned with assuring that the simulator carries out correctly the model instructions	basic comparison is at level 2; involves homomorphism at levels 3 or 4

Primary relations among entities (Cont'd)

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- modeling relation: validity
  - the relation between a model, a system, and an experimental frame
  - the degree to which a model represents its system counterpart
  - the model capture the system behavior only on objectives
  - ☛ whether it is impossible to distinguish the model and system **in the experimental frame of interest**
  - replicative validity
    - the behavior of the model and system agree within acceptable tolerance
    - I/O relation level 1
  - predictive validity
    - require not only replicative validity, but also the ability to predict behavior
    - the model needs to be set in a state corresponding to that of the system
    - I/O relation level 2

Primary relations among entities (Cont'd)

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- structural validity
  - require agreement of level 3 (state transition) or higher (coupled component)
  - the model
    - not only is capable of replicating the data
    - but also mimics in step-by-step, component-by-component fashion
- accuracy and fidelity
  - accuracy is often used in place of validity
  - fidelity is often used for a combination of both validity and detail

- simulation relation: simulator correctness
  - a relation between a simulator and a model
  - simulator correctness
    - it is guaranteed to generate the model's output trajectory given its initial state and its input trajectory
    - requires agreement at the I/O function level (level 2)
    - a simulator correctly execute a particular class of models
  - → correctness is proved by showing a *homomorphism* relation

Other important relationships

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- modeling as valid simplification
  - valid simplification
    - reduce the complexity of models to be executed on the resource-limited simulators
    - simplified model must also be valid
      - at some level and
      - within some experimental frame
  - base and lumped models
    - base models
      - more capable and more resources for interpretation than lumped model
      - valid within a larger set of experimental frames than lumped model
    - important point
      - the lumped model might be just as valid as the base model **in a particular frame of interest**
      - morphism can be a criteria for judging the equivalence of the base and lumped models

Other important relationships (Cont'd)

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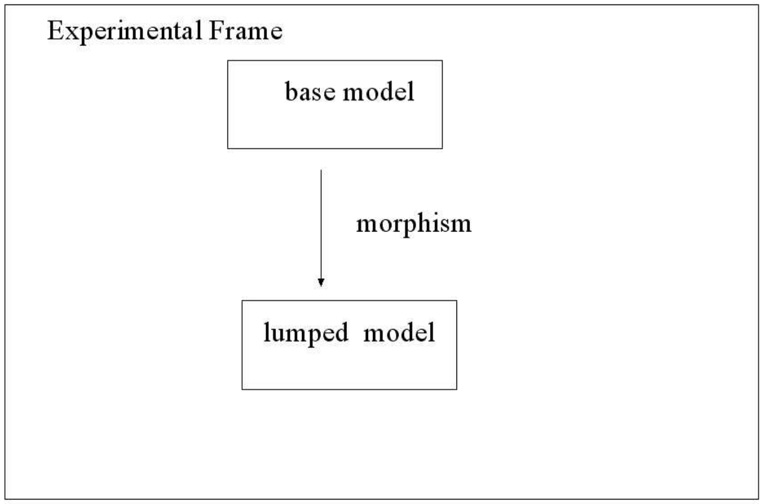

Other important relationships (Cont'd)

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- experimental frame: model relationships
  - applicability: if a frame can logically be applied to a model
  - accommodation: if a model can logically be applied to a frame

Relationship	Definition
Experimental frame applies to a model (or 'is applicable to')	the conditions on experimentation required by the frame can be enforced in the model
Model accommodates experimental frame	frame is applicable to the model
Experimental Frame 1 is derivable from Experimental Frame 2	any model that accommodates Experimental Frame 2 also accommodates Experimental Frame 1

Other important relationships (Cont'd)

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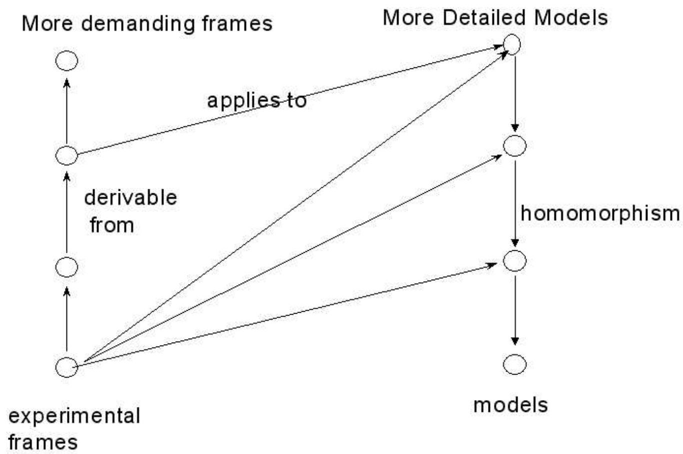
- derivability
  - ∗ A frame is derivable from B frame
  - ∗ A experimental frame is more restrictive in the conditions than B
  - ∗ A is less room for experimentation or observation than B



Time

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- logical time and real time
  - logical time: models the flow of actual time
  - physical time: measured by an actual clock
- local or global time
  - local time: valid only within a component of a system
  - global time: valid in the whole system

Time (Cont'd)

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		Logical/Physical	
		Logical Time	**Physical Time**
Local/Global	**Global Time**	Global Logical: All components operate on the same abstract time base.	Global, Physical: All components operate on the same system clock.
	Local Time	Local, Logical: A component operates on its own abstract time base.	Local, Physical: A component operates on its own system clock.