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Dynamic Model Updating in Simulation with Multimodels: A Taxonomy and a Generic Agent-Based Architecture

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## Goals

❑ to expand our horizons in multimodel formalism by exploring possible types of multimodels in terms of a comprehensive taxonomy.

❑ to present runtime dynamic model updating with multimodels as a potential strategy in dealing with uncertainty and multi-stage phenomena.

❑ to lay out the conceptual foundations for the realization of a specific subset of multimodels (relevant to conflict simulation) using the **agent paradigm.**

Plan

❑ Motivation

❑ Background on Multimodel Formalism

❑ Expanding Our Horizon: A Taxonomy of Multimodels

❑ Dynamic Model Update within Multimodels

  ▪ Why is Model Update Important?

  ▪ Requirements for Dynamic Model Replacement

❑ A Conceptual Basis for Agent-Based Multimodel Simulator

❑ Toward Multisimulation with Dynamic Simulation Updating

❑ Conclusions

Multimodels and Agent-Directed Simulation – The Connection
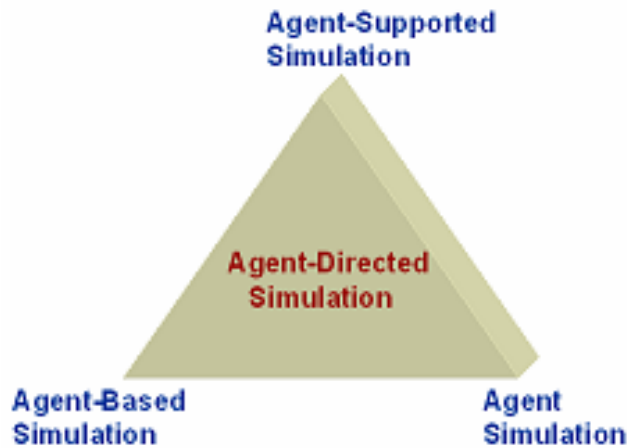
Agent Simulation: simulation of agent systems and technologies in several application areas such as: *engineering, management/economy, social systems.*

Agent-supported Simulation: use of agents in a simulation study to provide computer assistance for front-end and/or back-end interface functions.

Agent-Based Simulation: use of agents for the generation of model behavior in a simulation study - Agents as **model** and **simulator** design metaphors.

Using agents as model design metaphors is common. Yet, agent-based simulators are rare. Agent theory can facilitate realization of multisimulation by bringing adaptivity via run-time reasoning capabilities.

Improving the Simulation of Complex Conflict Phenomena

- **For most realistic complex phenomena the nature of the problem changes as the simulation unfolds.**

  – Conventional methodologies lack the flexibility and adaptivity to appropriately deal with uncertainty, as well as multi-stage phenomena.

  – **Need** to view available knowledge as being contained in the collection of modeling experiments that become plausible and viable given what is <u>known</u> or <u>learned.</u>

- **Problem: Run-time switching of models based on**

  – interpretation of emergent, potentially unforeseen conditions

    - to facilitate dynamic run-time model update and replacement for (simultaneous) experimentation with multiple simulation models.

Motivation: Adaptive Experience Management in Strategic Leadership Training with Contingency Models

ScenarioLine

Scenario: An inspection team under the command of the team of participants is at a weapons storage site in a fictional city. The inspection team discovers that weapons from the site are missing and that a hostile crowd is forming around them. As the inspection team radios for help, the members of the command staff must prepare and launch a rescue operation. Evidence begins to mount that the weapons were stolen by paramilitary troops who are motivating the hostile crowd. As additional paramilitary troops stream into the town, the command staff must overcome a series of obstacles in order to rescue the inspection team without incident or injury – A scenario from (Gordon and Iuppa 2003).

Contingency Models
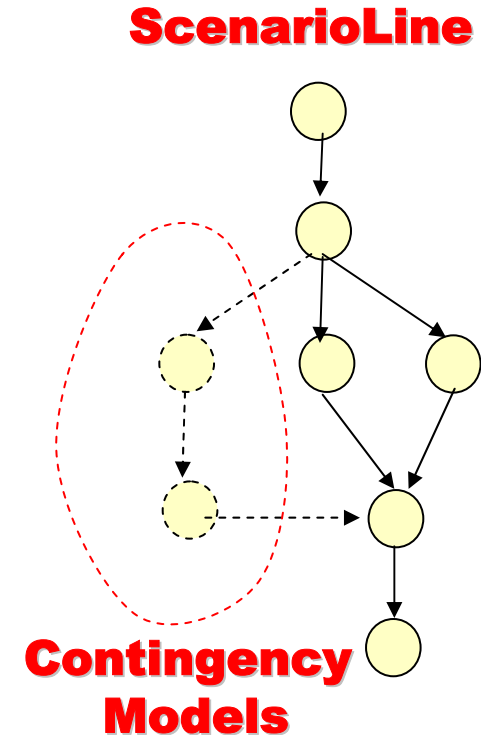
- Can we foresee all moves in a conflict? What if the original training scenario did not foresee a trainee decision that can result in civilian casualty?

- How can we provide to trainers as much freedom as possible, while assuring that the training goals are achieved by exerting control on the scenario flow?

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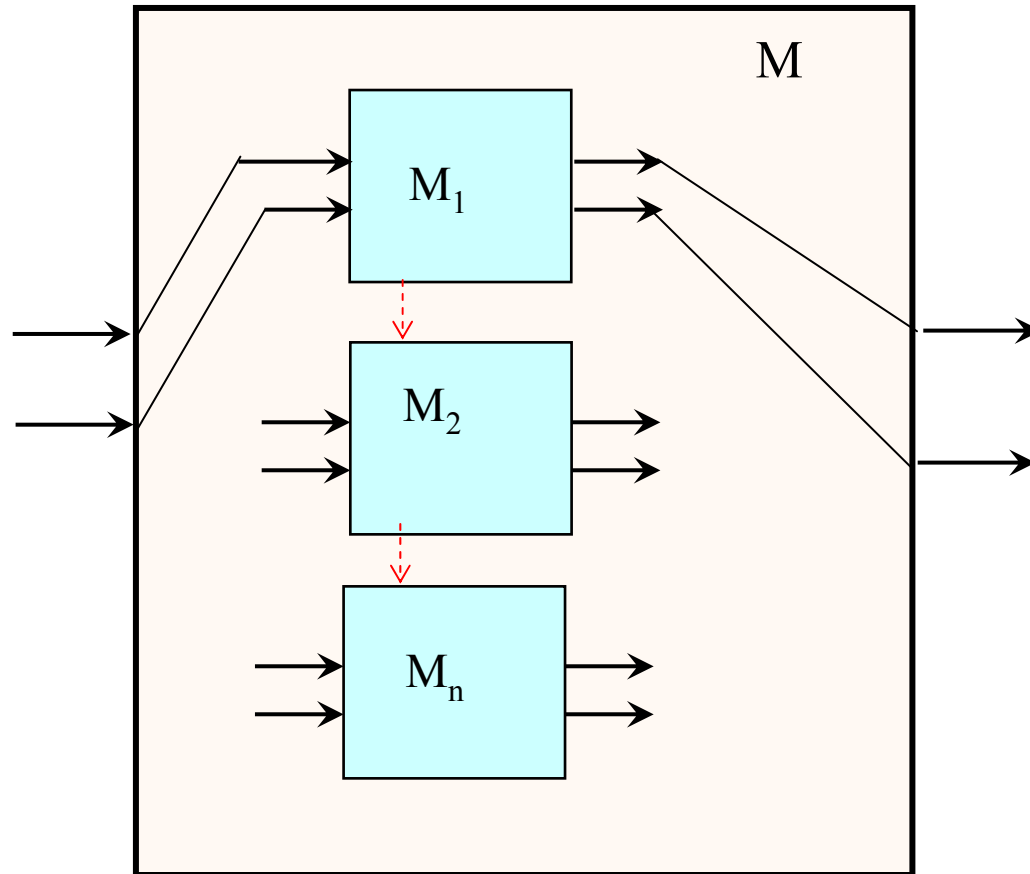
    ▪ Requirements for Dynamic Model Replacement

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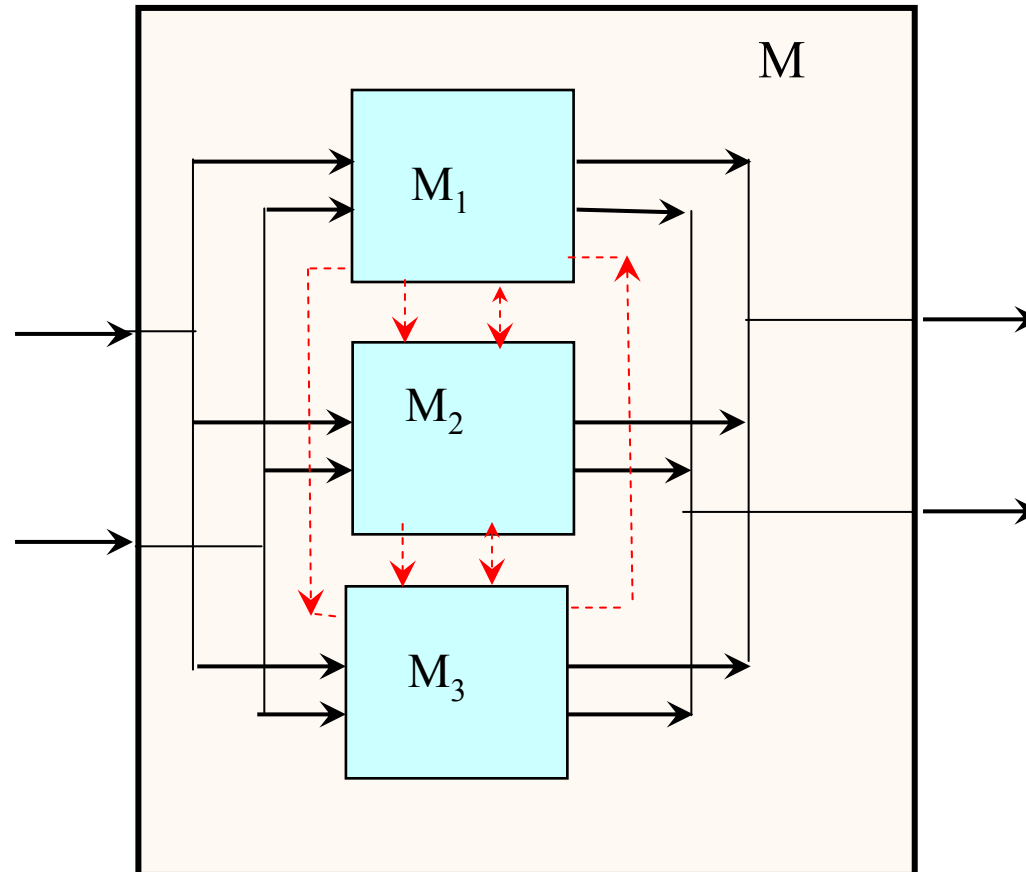There is a predefined <u>sequence</u> for the alternate models.

More than one alternate model can exist at the same time

with possible flows of entities (e.g., mass) between submodels

Multimodel Formalism: Background

- A multimodel is a modular model that subsumes multiple submodels that together represent the behavior of the model.

- Original formulation of multimodeling concept (Ören 1991) inspired the development of

  - combined simulation (Praehofer 1992) - integration of continuous and discrete simulations within the same system description.

  - multimodel formalism for analyzing the qualitative dynamics of systems (Fishwick and Zeigler 1992).

- In existing formalisms submodels

  - share the same address space, and they are updated based on programmatic switch statements; hence, they are not only inflexible (i.e., hardwired), but also lack applicability to truly distinct arbitrary models.

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Taxonomy of Multimodels (Submodel Structure)
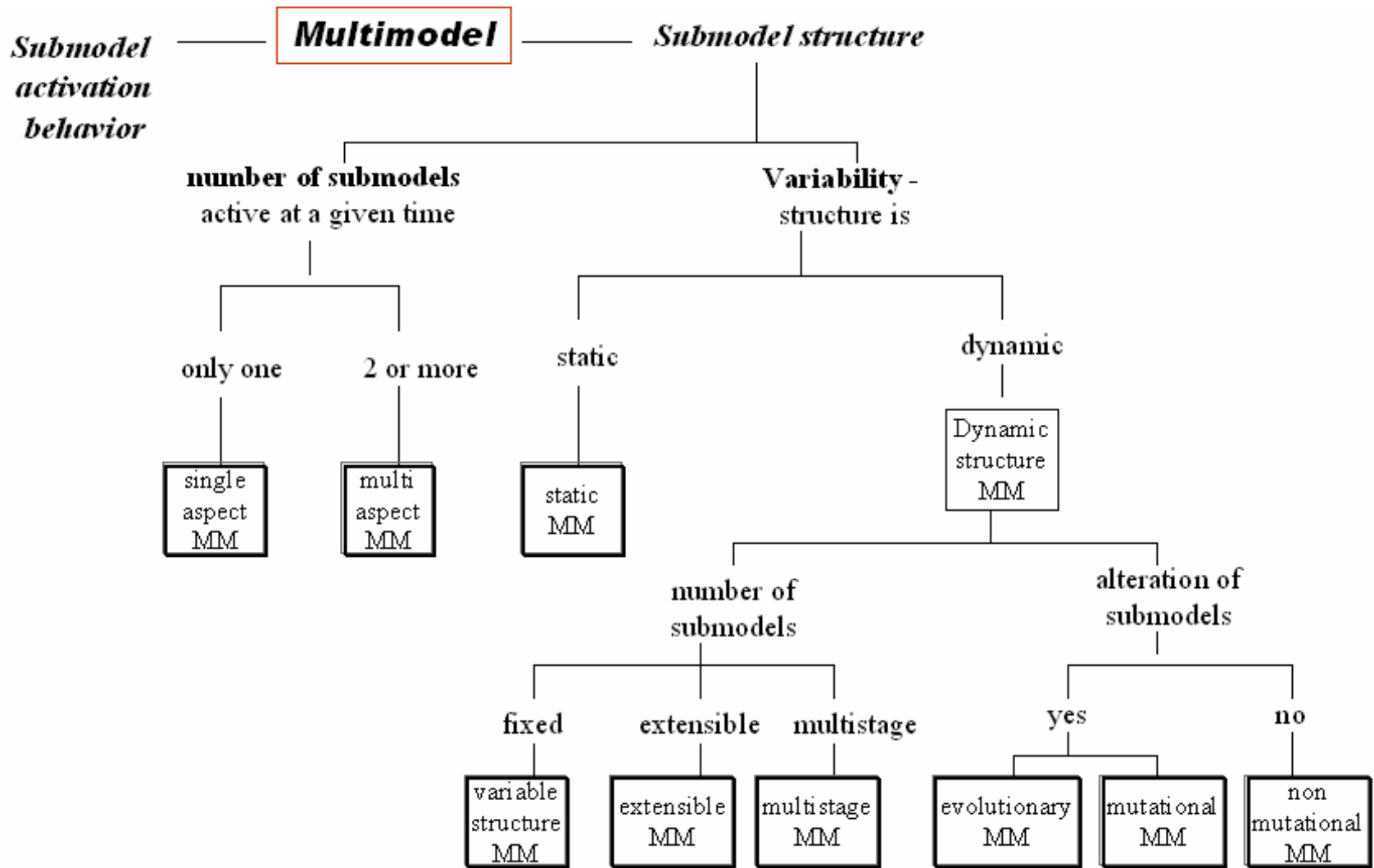
Taxonomy of Multimodels (Submodel Activation Behavior)
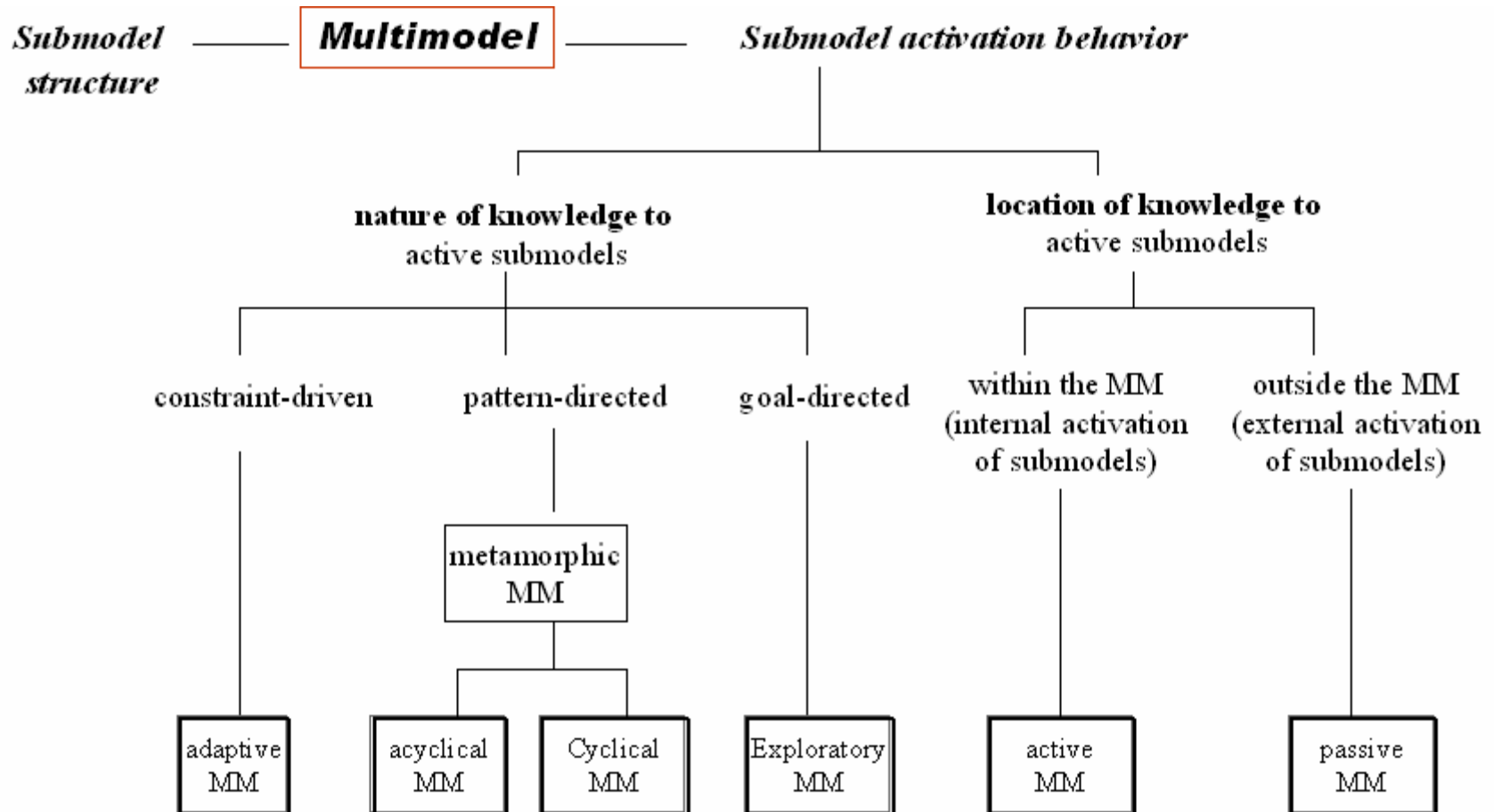
A Strategy - Dynamic Model Update with Multimodels

- **<u>Why</u> and <u>When</u> Dynamic Model Update is Needed?**

Changing Scenarios: For most realistic social dilemmas, the nature of the problem changes as the simulation unfolds.

Ensembles of Models: Our knowledge about the problem (i.e., conflict) being studied may not be captured by any single model or experiment.

Uncertainty: Adaptivity in simulations and scenarios is necessary to deal with emergent conditions for evolving systems in a flexible manner.

Exploration: As simulations of complex phenomena are used to aid intuition, dynamic run-time simulation composition will help identify strategies that are flexible and adaptive.

Technical Challenges for Dynamic Model Replacement

Activation: Submodel replacement must be initiated, either internally by a submodel or externally by a scheduler.

Integrity: The consistency of submodels undergoing replacement needs to be preserved.

Submodel Instantiation: The new (or selected) submodel must be dynamically loaded and linked into the run-time environment of the simulator (simulation engine).

State Reconstruction: The state of a model must be reconstructed when re-instantiated after an update operation. This requires externalization through abstraction, state saving, transmission, and reconstruction.

Simulator Rebinding: Once a model is loaded and linked to the run-time environment, the simulator needs to be bound to the new model.

Toward Agent-Based Multimodel Simulators
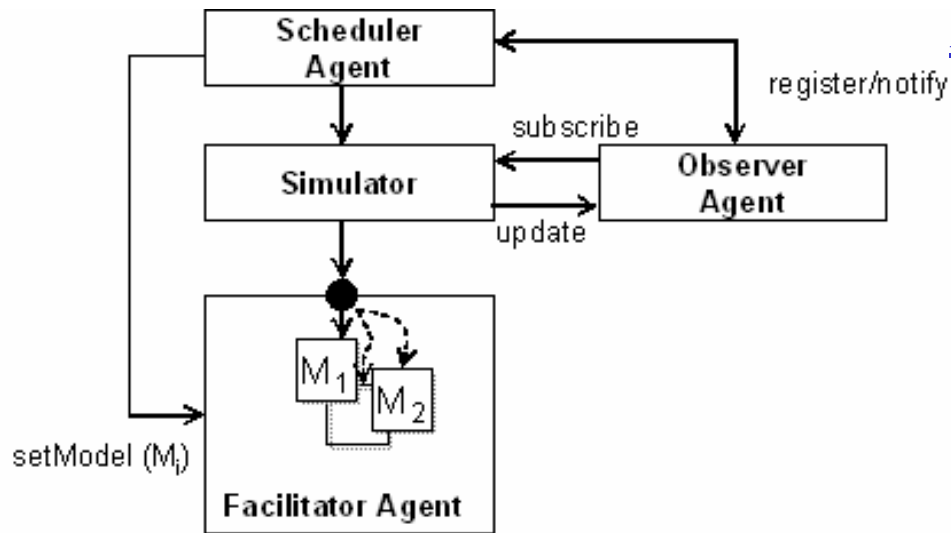
Architectural Requirements:

- observe simulation state,
- reason to qualify models for update,
- facilitate model (re)binding, and
- plan for goal-directed activation by exploring potential paths within the state space of problem domain.

• Agents are capable of **observing**, **perceiving**, and **reasoning** about their environment to act or proact with goal-driven responses.

• The underlying rationale for using facilitator is to bridge the gap between resources (i.e., simulator, model) through a level of indirection.
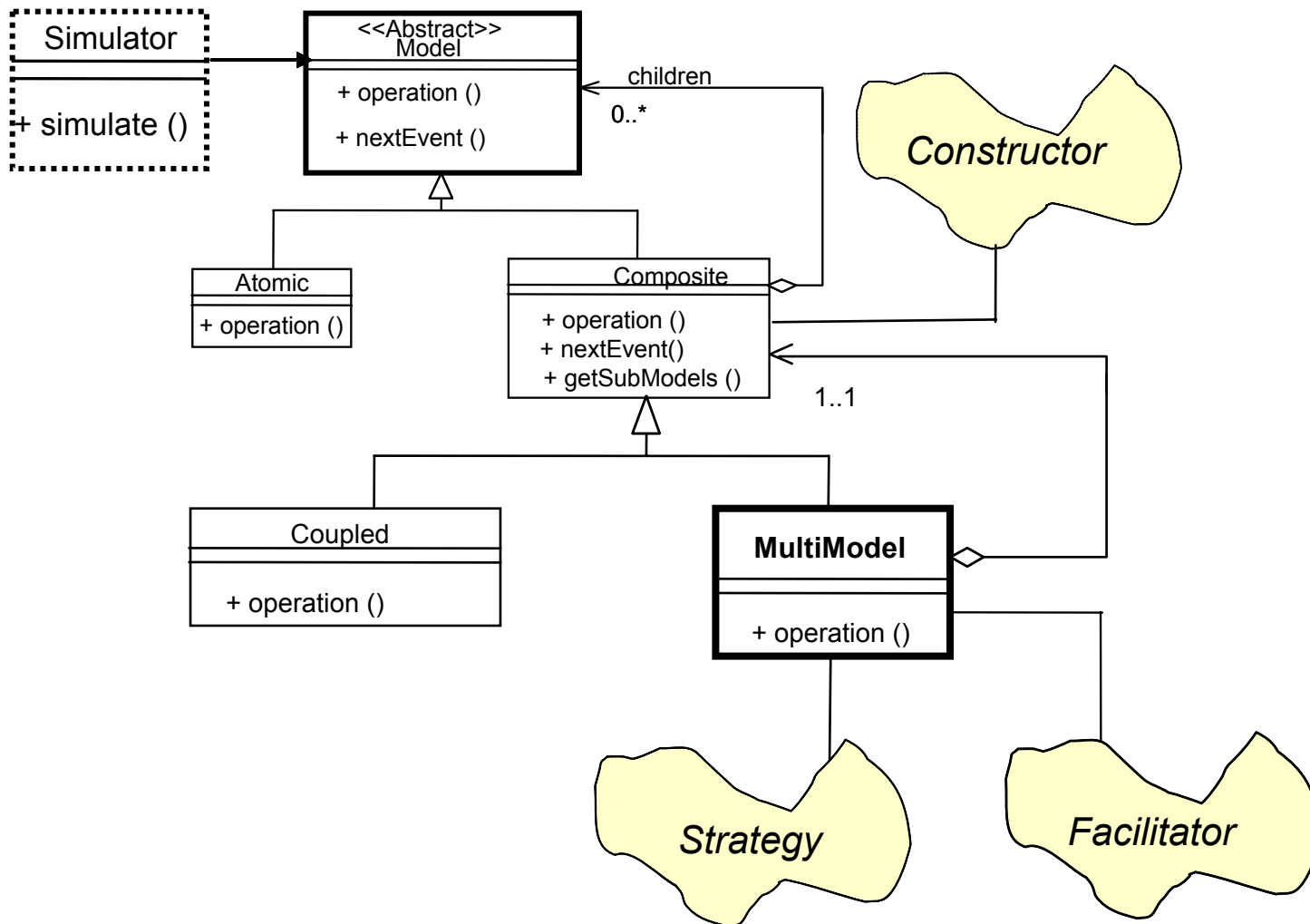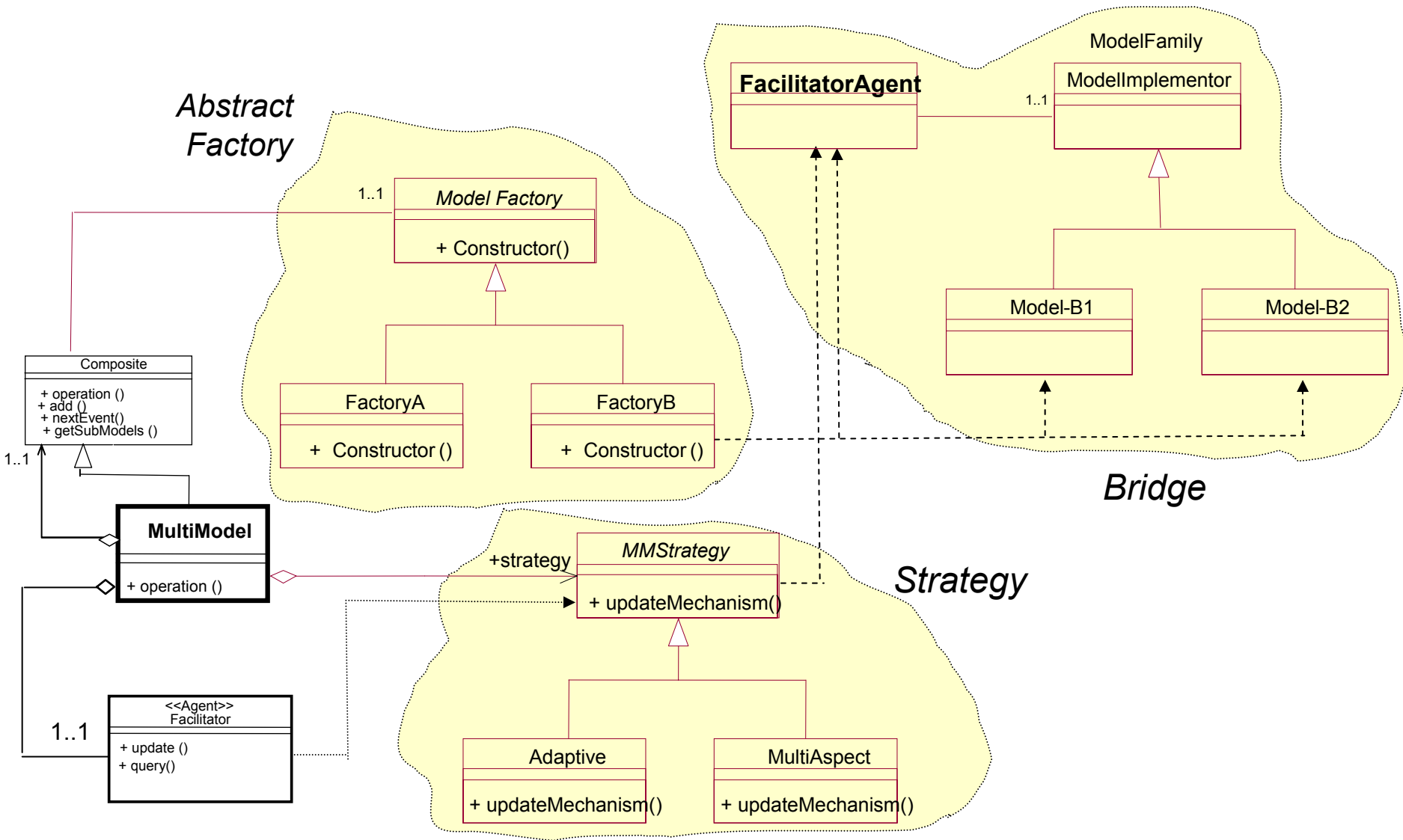
Facilitating Dynamic Model Replacement
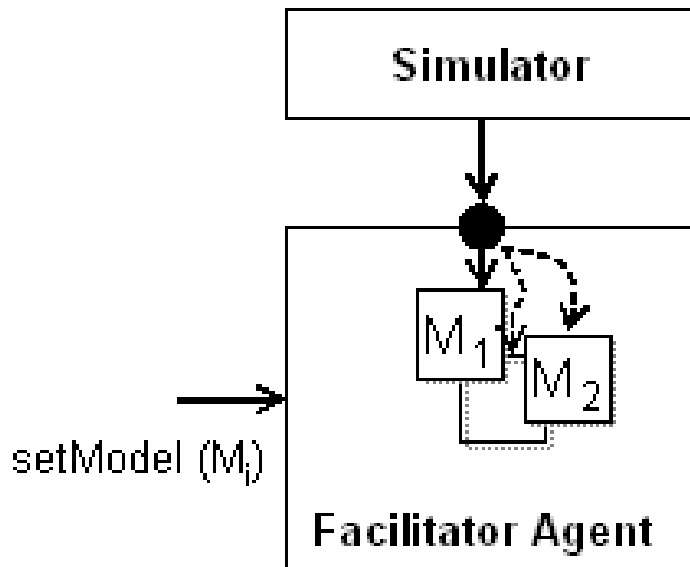
- The model should be independent of how its submodels are created, composed, and represented.

- The model can be configured with one of multiple families of models.

- The facilitator provides a permanent level of indirection between the simulator and the model objects that can be exchanged at run-time

Need to decouple a simulator from the set of submodels to enable run-time dynamic update. The facilitation mechanism embodies decorator, strategy, and abstract factory patterns that are coupled to enable seamless model replacement.
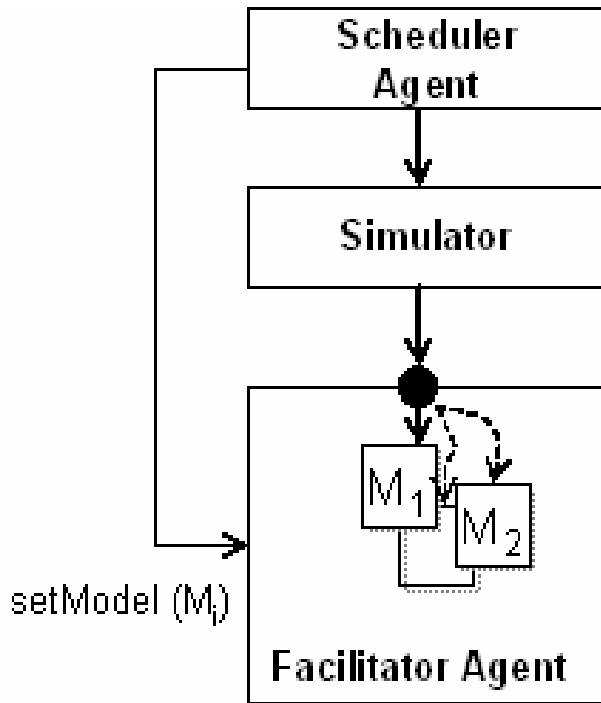
# A Conceptual Basis for the Facilitation Mechanism

Facilitator Agent and Dynamic Model Binding

ModelFamily

FacilitatorAgent

ModelImplementor

1..1

Model-B1

Model-B2

Bridge

Abstract Factory

1..1

Model Factory

+ Constructor()

FactoryA

+ Constructor ()

FactoryB

+ Constructor ()

Composite

+ operation ()
+ add ()
+ nextEvent()
+ getSubModels ()

1..1

MultiModel

+ operation ()

+strategy

MMStrategy

+ updateMechanism()

Strategy

<<Agent>>
Facilitator

+ update ()
+ query()

1..1

Adaptive

+ updateMechanism()

MultiAspect

+ updateMechanism()

Scheduler Agents: Goal-Directed Exploration

- External activation of submodels requires facilities to guide submodel selection process.

- While a predefined pattern for model switching is possible, goal-directed exploration may be needed in cases where uncertainty exists

- A scheduler agent can have planning capability that drives a simulator with alternative models by updating the parameterized model facility (i.e., facilitator).
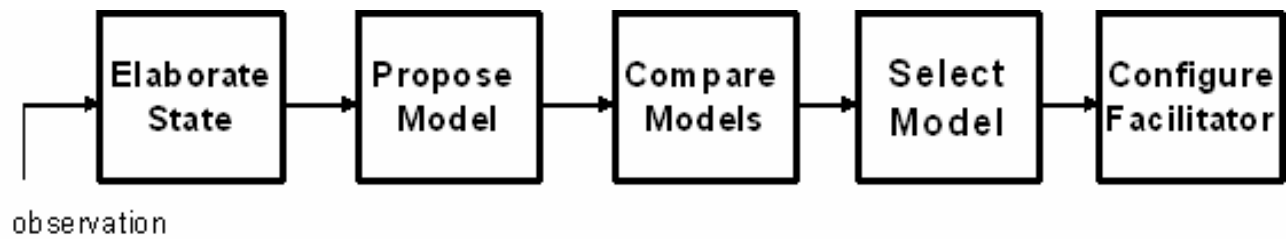
Observer Agents: Observing Model Update Conditions
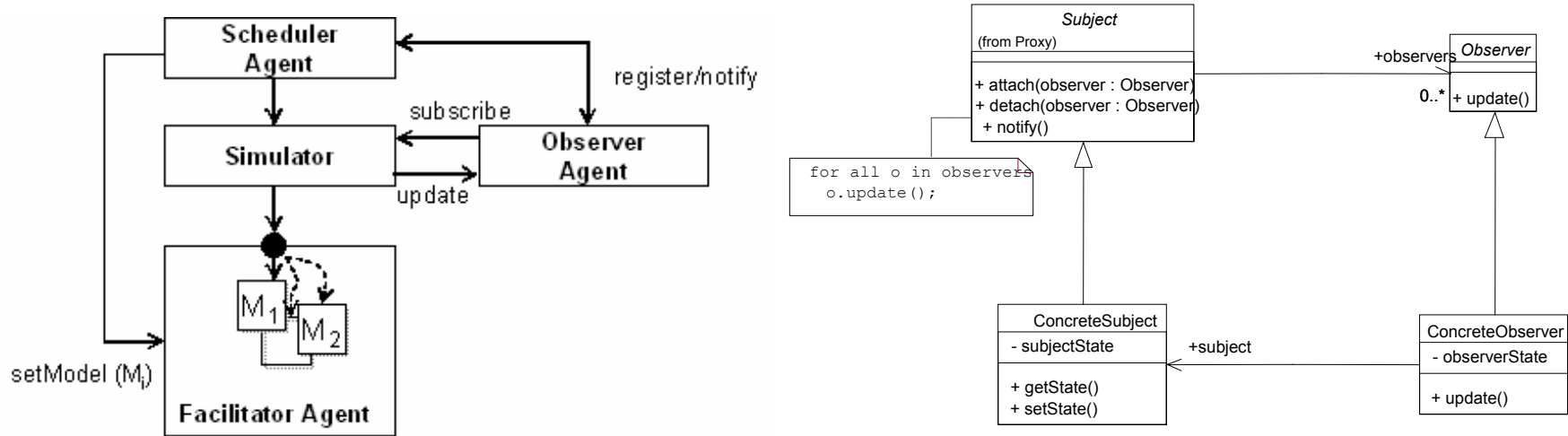
- Need to notify scheduler agent of the change using observer components
  - The number of observers may not be known. Each observer is responsible for specific states of interest in the application domain.
  - The strategy requires simulator and observer to be loosely coupled
- Multimodel abstraction requires realization of two aspects,
  - the view (observer) aspect, and
  - the behavior generator (subject) aspect.

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Toward Multisimulation with Dynamic Simulation Updating

• **Multisimulation** (or multisim, for short) is simulation of several aspects of reality in a study. It includes
   •simulation with single aspect multimodels,
   •simulation with multiaspect models, and
   •simulation with multistage models.

• **Simulation with sequential multimodels** allows computational experimentation with several aspects of reality.
• **Simulation with multiaspect models** (or multiaspect simulation) allows computational experimentation with more than one aspect of reality simultaneously.
• **Simulation with multistage models** allows branching of a simulation study into several simulation studies
   • Multistage simulation, is a novel way to perceive and experiment with several aspects of reality as well as exploring conditions affecting transitions between several aspects of systems, especially social systems.
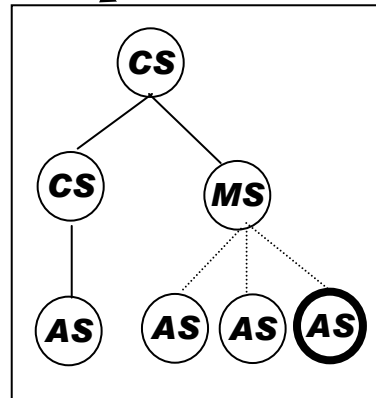
Simulation Branching with Multisimulation

frame 1
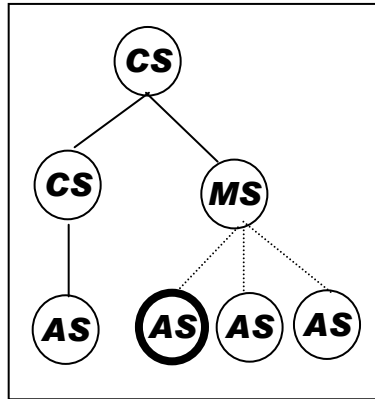
frame 1.1
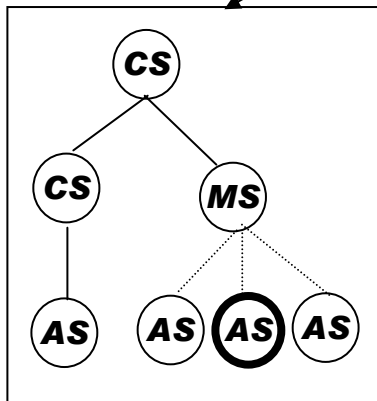
frame 1.2

(1) Select one of them and ignore others. This approach is similar to many cases in traditional simulation where implicit assumptions are not brought to the users attention. (This alternative is not a good one and definitely is not our choice.)

(2) Perform an ordered simulation in breadth or depth first manner with alternative contingency models. (In this case, the user cannot easily and intuitively follow the consequences of alternative simulation studies.)

(3) Select multisimulation branching (for all or some of them) and observe (visually or through metrics) behavioral and/or structural developments in simulation studies executed in parallel.

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• **Multimodeling** formalism inspired the development of several methodologies, including

  • combined simulation [Preahofer 1992],
  • FSA-controlled multimodeling [Fishwick and Zeigler 1992], and
  • MOOSE [Cupert and Fishwick 1997].

• Yet, we are still scratching the surface of what is possible with the very basic dynamic model update concept.

• **Agent-based** approach presents a reasonable strategy to realize multimodel simulators.

• However, more effort is needed to identify and implement intricate details of **observing/interpreting** the simulation state, **reason** to qualify models for update, facilitate run-time model **rebinding**, and **plan** for goal-directed activation of submodels.

Thank you for your attention !

Questions ?