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Exploring Agent-Supported Simulation Brokering on the Semantic Web: Foundations for Dynamic Composability

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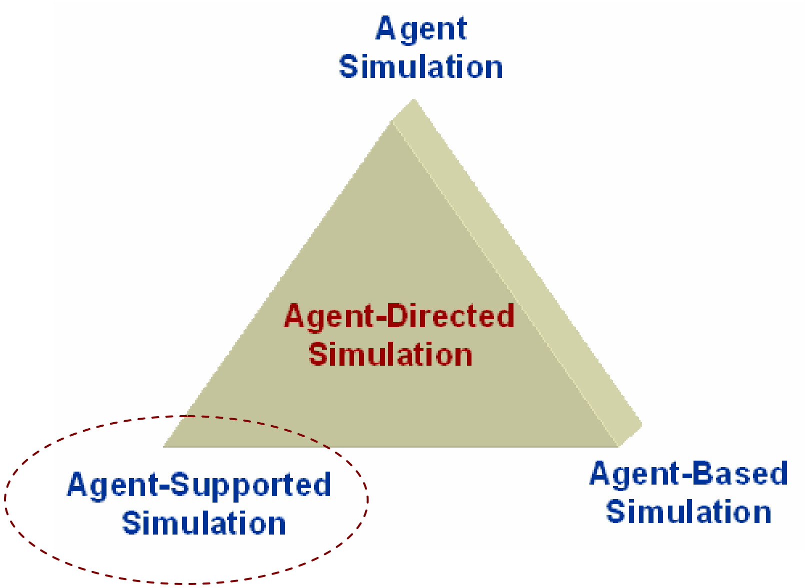
Goals

- to point out the significance of improving dynamic composability of simulation models,
- to argue about the fundamental requirements for model and simulation updating



- to emphasize the potential role of synergistic combination of agent technology and semantic web initiatives to perform
  - intelligent **brokering** and **matchmaking** between intentions (simulation needs) and published advertisements of simulation services.

Plan

- **Motivation: The need for dynamic model and simulation updating**
- Toward Dynamic model and simulation updating with multimodels and multisimulation on the semantic web
  - Requirements for simulation updating
  - Semantic web and its potential for (dynamically) extensible simulations
  - Agent-supported brokering of simulations for dynamic simulation update
  - Agent-supported matchmaking to improve accuracy and relevance in updates
- Conclusions

Toward Open and Extensible Simulations

- While federated simulation concept improves reusability, the integration decision of a federation still takes place at design time.
- Yet, most realistic problems require scenario evolution that calls for flexibility and adaptivity in simulations **with capabilities to**
  - to discover,
  - locate, and
  - instantiate new federates

consistent with emergent conditions.

The Role of Specifications

Yet, the lack of machine processable formal annotations is a fundamental roadblock, as such information pertains to

(1) finding and matching candidate models,

(2) infer limits on the use and interpretation of federates, and

(3) perform run-time mediation and facilitation (i.e., translation) among disparate federates.

to facilitate composability as envisioned here, advances in the following areas are taking place:

Formalisms: to form the basis of annotating models with profiles that include assumptions, objectives, and constraints.

Ontologies: domain-specific specification to capture various facets of models and simulators.

to facilitate composability as envisioned here, advances in the following areas need to take place:

Profiles: annotation with a schema that describes the services they provide in terms of domain-specific ontologies.

(1) declarative advertisements of relevant model properties and capabilities,

(2) declarative APIs of models for execution, and

(3) declarative specification of the assumptions and obligations

Tools: to perform inference and make run-time decisions about composing candidate models. (i.e., operate on contextualized introspective models)

Why Dynamic Composability?: Dynamic Model and Simulation Update in Support of Extensible Simulations

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

- Our knowledge about the problem being studied may not be captured by any single model or experiment. Instead, the available knowledge is viewed as being contained in the collection of ensemble of models that are plausible given what is known and what is learned during experimentation.

- Dealing with uncertainty is paramount to analyzing complex evolving phenomena. Adaptivity in simulations and scenarios is necessary to deal with emergent conditions for evolving systems in a flexible manner.

Multimodels and Multisimulation

Appendix A. A Synopsis of Multimodel (MM) Formalisms

Based on	Additional Criteria				Type of multimodel (MM) (Synonyms are represented within parentheses)
Structure of submodels	**Number** of submodels active at a given time			Only one	Single aspect MM (Sequential MM)
				2 or more	Multiaspect MM
	Variability of structure (variability of number of submodels)	**Static**			Static-structure MM
		Dynamic (Dynamic-structure MM) (Variable-structure MM)	Number of submodels	Extensible	Extensible MM
				Depends on model's stage	Multistage MM
			Alterations of submodels	No	Non-mutational MM
				Yes	Mutational MM Evolutionary MM
Behavior (activation) of submodels	**Nature of knowledge** to activate submodels	Constraint-driven			Constraint-driven MM (Adaptive MM)
		Pattern-directed (Pattern-directed MM) (Metamorphic MM)	Submodel selection is cyclic	No	Acyclic MM
				Yes	Cyclic MM
		Goal-directed			Goal-directed MM (Exploratory MM)
	Location of knowledge to activate submodels	Within the MM (Internal activation of submodels)			Active MM (Internally activated MM)
		Outside the MM (External activation of submodels)			Passive MM (Externally activated MM)

- A **multimodel** is a modular model that subsumes multiple submodels that together constitute the behavior of a complex multi-phased process.

- **Multisimulation** is a simulation methodology where at decision points, simulation updates may include
  - decisions on the branching of simulation studies
  - selection of submodels and associated parameters and experimental conditions to be used in subsequent stages of simulations.

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Requirements for Model and Simulation Updating

This paper's focus

Requirement	Objective
Discovery and Location	Federate (re)placement must be initiated, either internally by the federation or externally. New federates must be discovered, located, and activated (pulled) for inclusion in the federation.
Integrity	
Instantiation	
State (re)construction	
Rebinding	

Requirements for Model and Simulation Updating

Requirement	Objective
Discovery and Location	
Integrity	The consistency of federates (model components) undergoing (re)placement needs to be preserved. The event scheduling and simulation protocol need to be coordinated to facilitate interleaving of model replacement (update) tasks with the simulation events.
Instantiation	
State (re)construction	
Rebinding	

Requirements for Model and Simulation Updating

Requirement	Objective
Discovery and Location	
Integrity	
Instantiation	The new federate (model component) must be dynamically loaded and linked into the run-time environment of the federation.
State (re)construction	
Rebinding	

Requirements for Model and Simulation Updating

Requirement	Objective
Discovery and Location	
Integrity	
Instantiation	
State (re)construction	The state of a federate must be constructed or at least continue from a specific state after an update operation.
Rebinding	

Requirements for Model and Simulation Updating

Requirement	Objective
Discovery and Location	
Integrity	
Instantiation	
State (re)construction	
Rebinding	Once a federate model is loaded and linked to the run-time environment, the federation needs to be bound to the new model (federate). This requires novel model and simulator decoupling strategies that avoid persistent or permanent connections.

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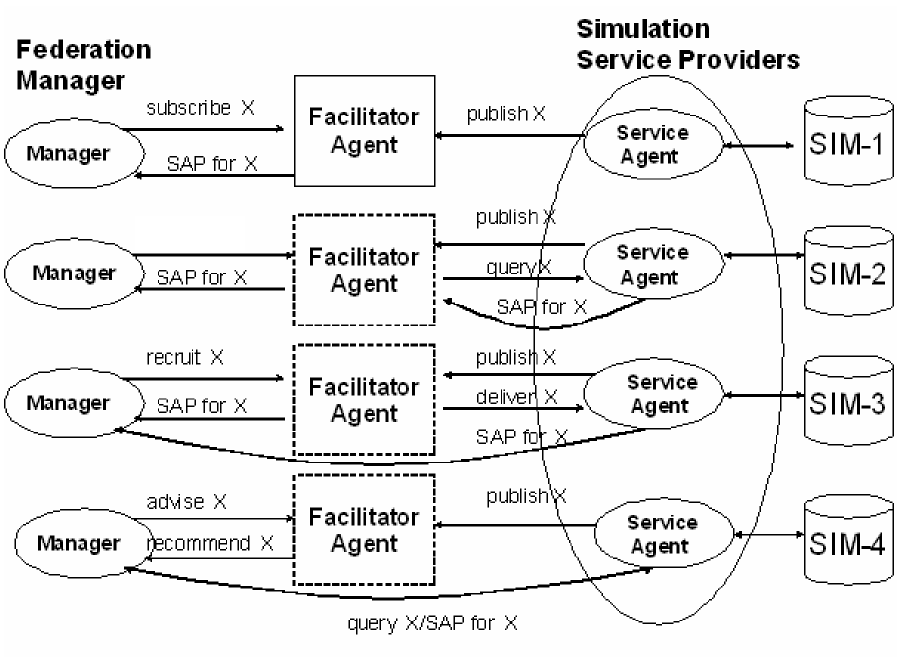
Simulation on the Semantic Web

Automatic federate (service) discovery involves the automatic location of simulations that provide a particular service and adhere to requested constraints.

Automatic federate (service) instantiation involves the invocation and execution of a qualified federate. OWL-S markup of services provides a declarative, computer-interpretable API for executing these interaction capabilities within the scope of its protocol.

Federate (service) composition and interoperation: With OWL-S markup of federates, the information necessary to select and compose services can be encoded and advertised to be brokered by intelligent agents with ontology processing capabilities.

simulation brokering can follow different specific modes as shown in the figure:



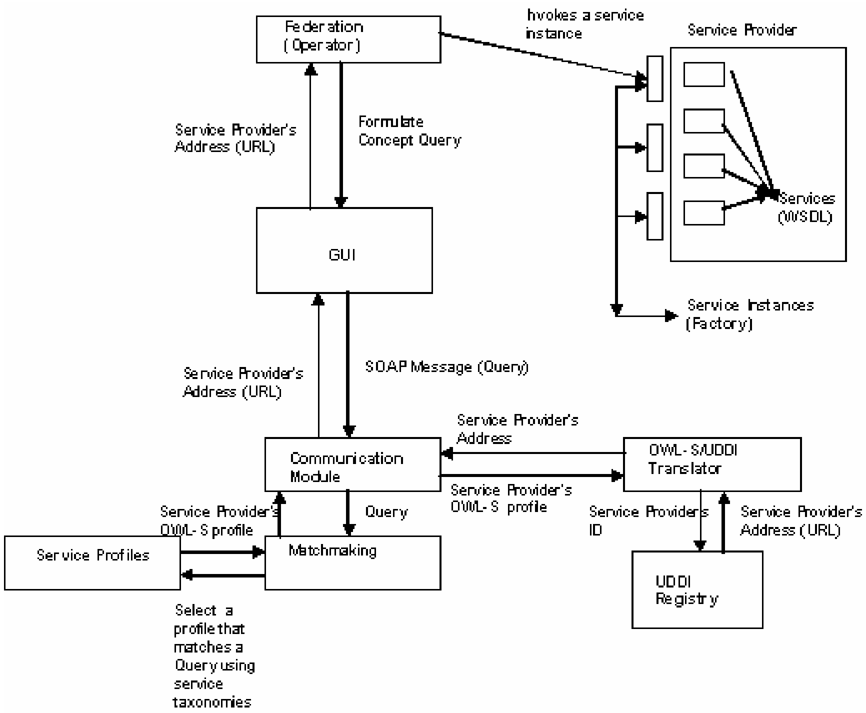
The consumer may subscribe to an interest group to be **notified** when a *sufficiently relevant* model is published by a service provider.

Recommendation protocol requires the federation manager ask the facilitator to recommend a simulation service provider.

The manager can also **recruit** the facilitator forward the request to a capable provider with the stipulation that future negotiation takes place directly between the manager and the service provider.

Mediation may be required in cases where all interaction is required to take place through the facilitator.

The Architecture of the Facilitator



Currently, **federation (operator)** emulates the role of the federation manager.

The **communication module** is responsible for enabling exchange of data and queries among the federation manager and matchmaker.

Matchmaking engine performs multiple levels of partial (inexact) matching between user intentions and profiles available in the service profiles database

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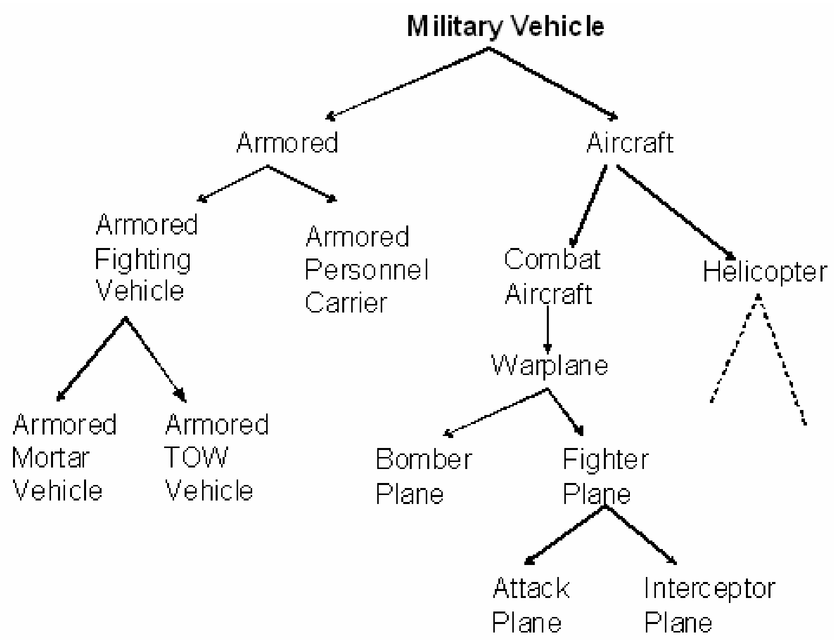
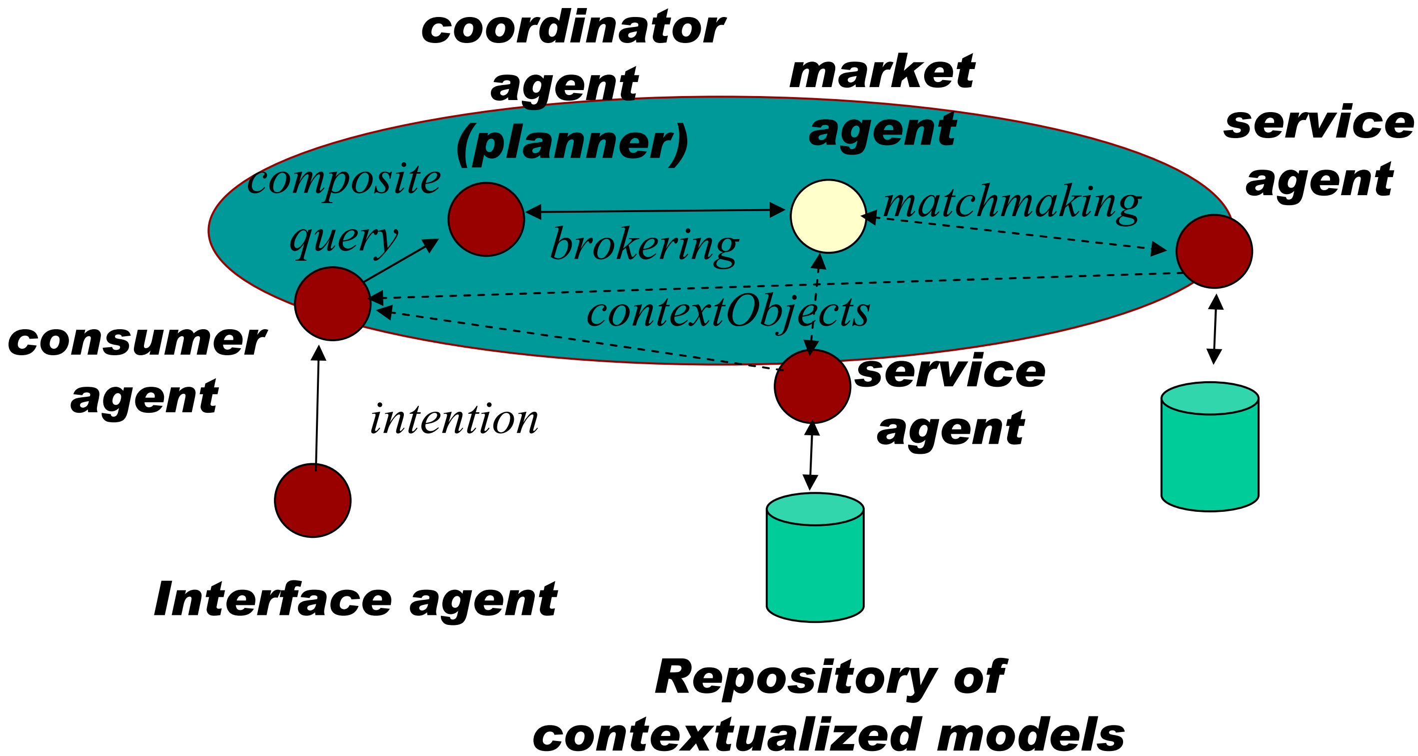
Partial, Inexact Matchmaking using Concept Similarity Analysis



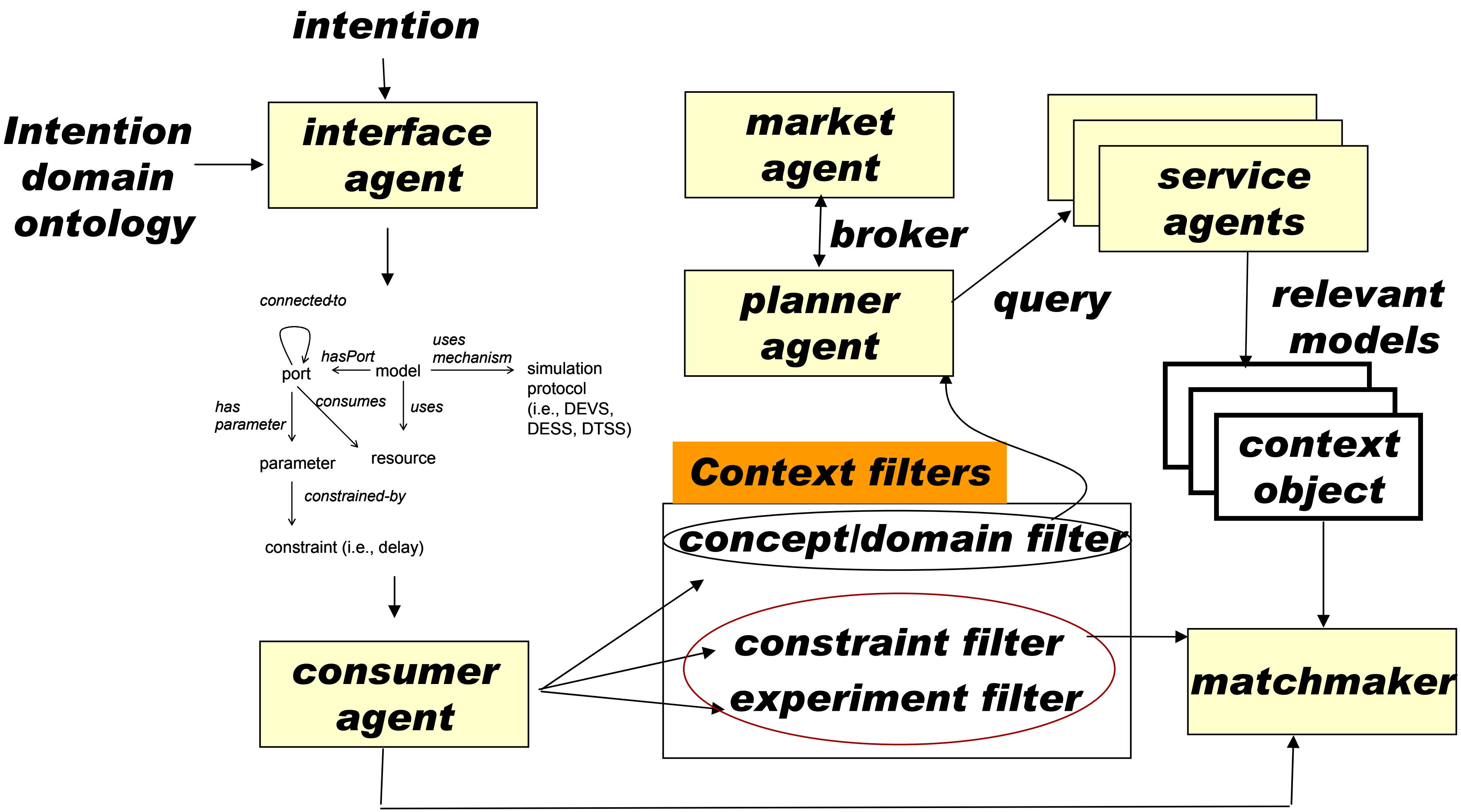
Based on the location of the query concept (*Q*) and advertised model *(A)* within the ontology, there are four cases to consider:

- If *Q=A* then the query and advertisement are equivalent and there is an exact match between the concepts.
- If *A is a subtype of Q* then the federate is substitutable for the requested concept.
- If *Q is a subtype of A* then the advertised federate can be used with slight modifications to perform the desired tasks.
- If there is *no subsumption relation* between the advertised concept *A* and *Q* then the query fails.

Application: Toward High-Precision Retrieval of Contextualized Introspective Simulation Models



Matching Intentions to Contextual Assumptions



Conclusions

- We have
  - discussed significance of dynamic composability of simulation models,
  - argued about the fundamental requirements for dynamic model and simulation updating,
  - discussed a generalized and unifying viewpoint in multimodel formalism and multisimulation to signify the utility and practical value of simulation updating.
  - discussed the potential role of synergistic combination of agent technology and semantic web initiatives to perform
    - intelligent **brokering** and **matchmaking** between intentions (emergent simulation needs) and published advertisement of simulation services.