TECHNION
ISRAEL INSTITUTE OF TECHNOLOGY

MIT ESD
Engineering Systems Division

INCOSE International Symposium
Las Vegas, NV
June 30 - July 3, 2014

Conceptual Modeling of System-Based Decision Making

Yaniv Mordecai & Dov Dori

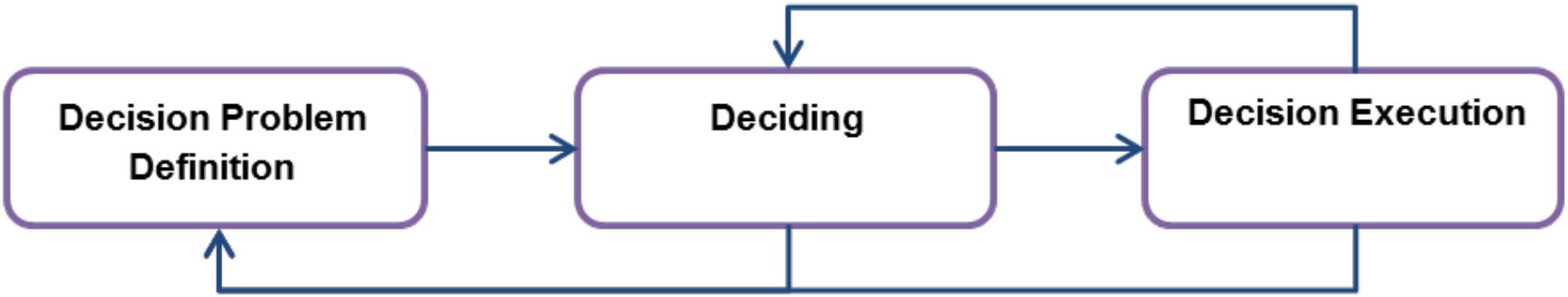
Decision

Selection of a preferable solution or course of action, from a set of alternatives, based on comparative evaluation according to defined criteria.

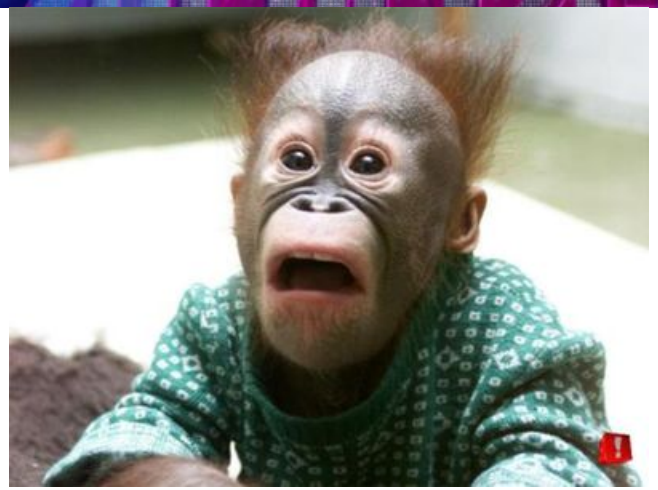
Decision Making

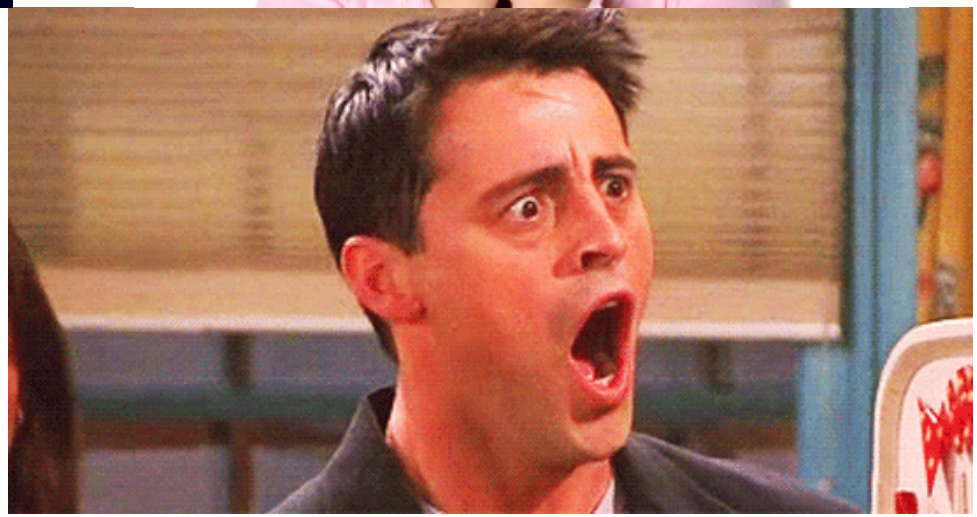
The process of planning, generating, and executing a decision

A Decision-Based Process



Systems Make Decisions!

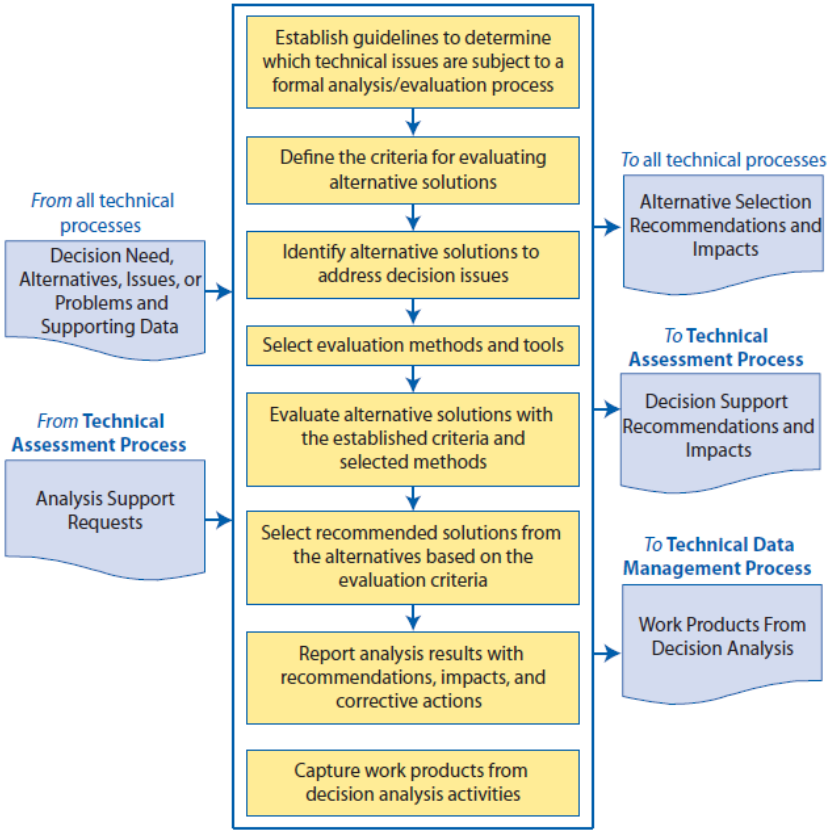




Some Self-Criticism Regarding Decision Making & Systems Engineering

- Our literature mostly focuses on how to **make decisions as systems engineers**.
- We're lagging behind with developing a body of knowledge on how to **automate decision making in engineered systems**.

NASA Sys. Eng. Handbook Decision Analysis Process



Criteria for Defining Requirements for ADM

- Complex conditionality
- Dependency on various combinations of input and state indicators
- Rigid or flexible preference relations
- Adaptive selection from a set of alternatives

Decision Automation Evolution over the last decade

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- Closed circuit feedback control of engineering devices.
- Intelligent agents and agent-oriented architectures.
- Evolution of decision execution capabilities:
  - sensors , actuators, and intelligence at the palm of your hand, and at the tip of your finger.
  - Delegation of cognitive tasks to intelligent devices.
- Evolution of cyber-physical systems and especially of the cyber-physical approach to systems (next slide).
- The future: Internet of Things (IoT)

Cyber-Physical Systems

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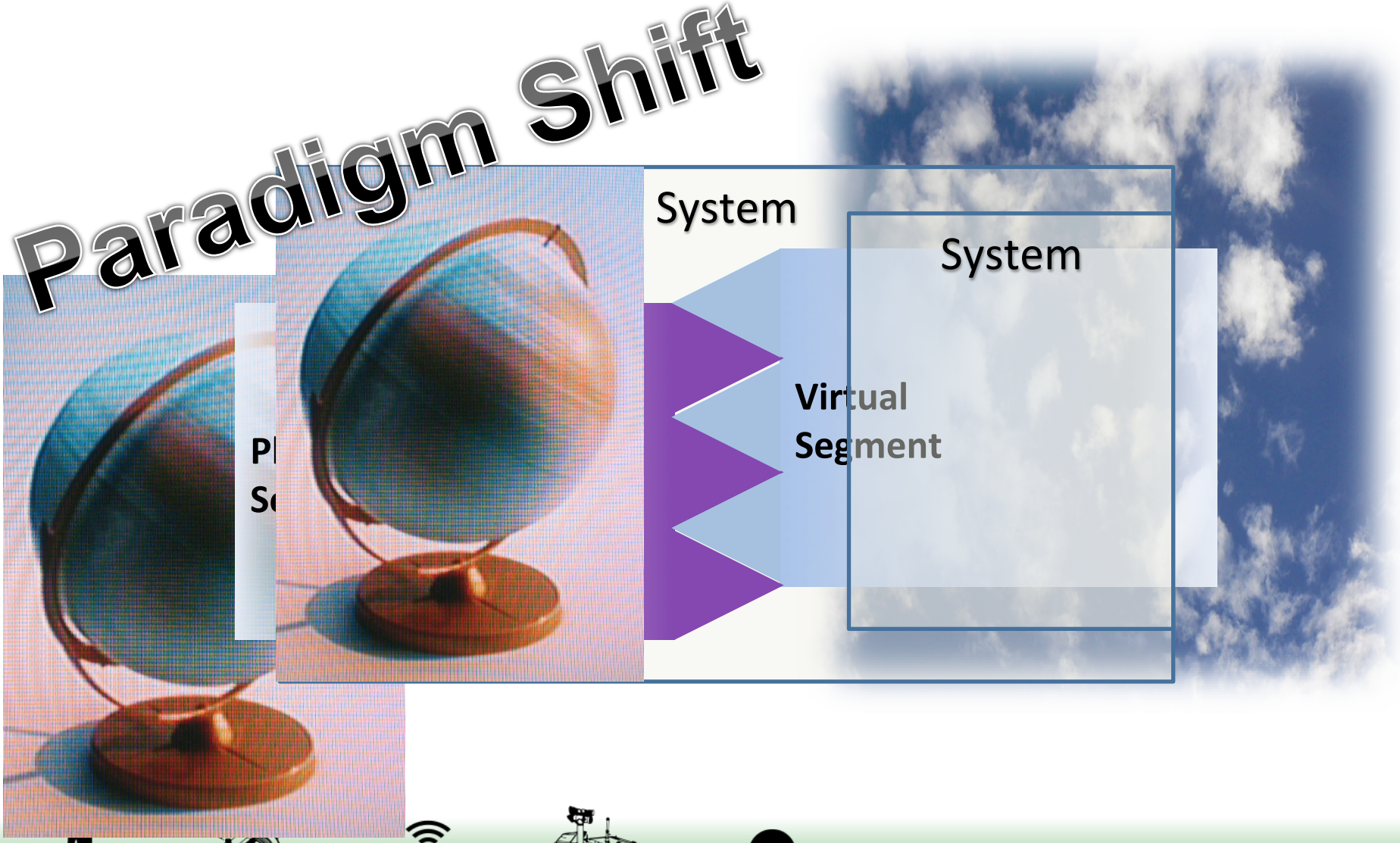

Cyber-Physical Domains

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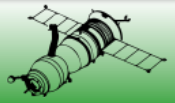
Cyber defense	Information Security	Cyber-medicine and mobile health
Internet of Things	Missile Defense	Air Traffic Control
Autonomous Vehicles	Robotics	Biological Systems


Challenges in Decision Automation

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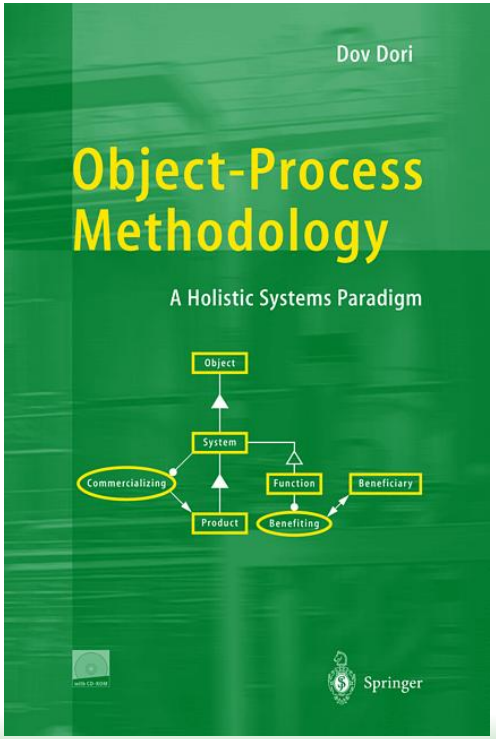
- System designers are no decision analysis specialists.
- Systemic decisions are often degenerated to simplistic criterion-based selection. if x>p, then a(), else b()
- Integrating advanced system design (e.g., UML models) with legacy decision models (e.g., decision trees, MCDM, AHP models).
- DM authority allocation to system nodes.
- Capturing human preferences in the automated decision model.
- Justification and rationalization of decisions for and by human decision users (who are often irrational…)
- Regulation, control and intervention by operators.

Object-Process Methodology (OPM) (Dori, 2002) (ISO PAS 19450)

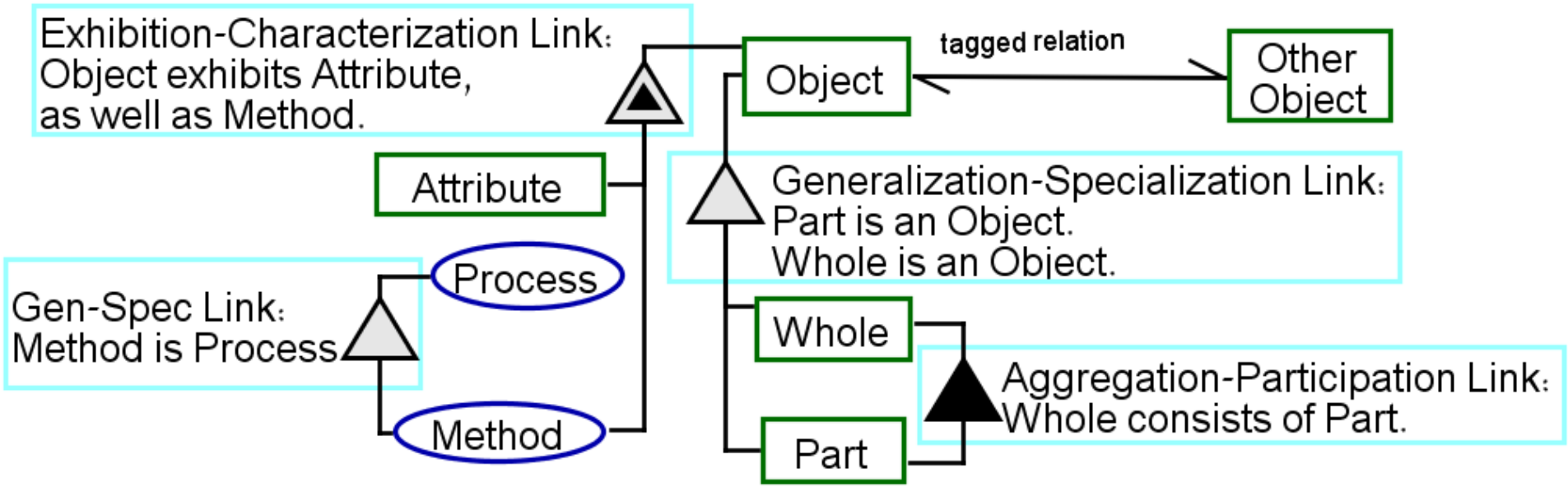
- **Object**
  - Exists
  - Has **states**
  - Modified by **Processes**
- **Process**
  - Occurs
  - Modifies **Objects**



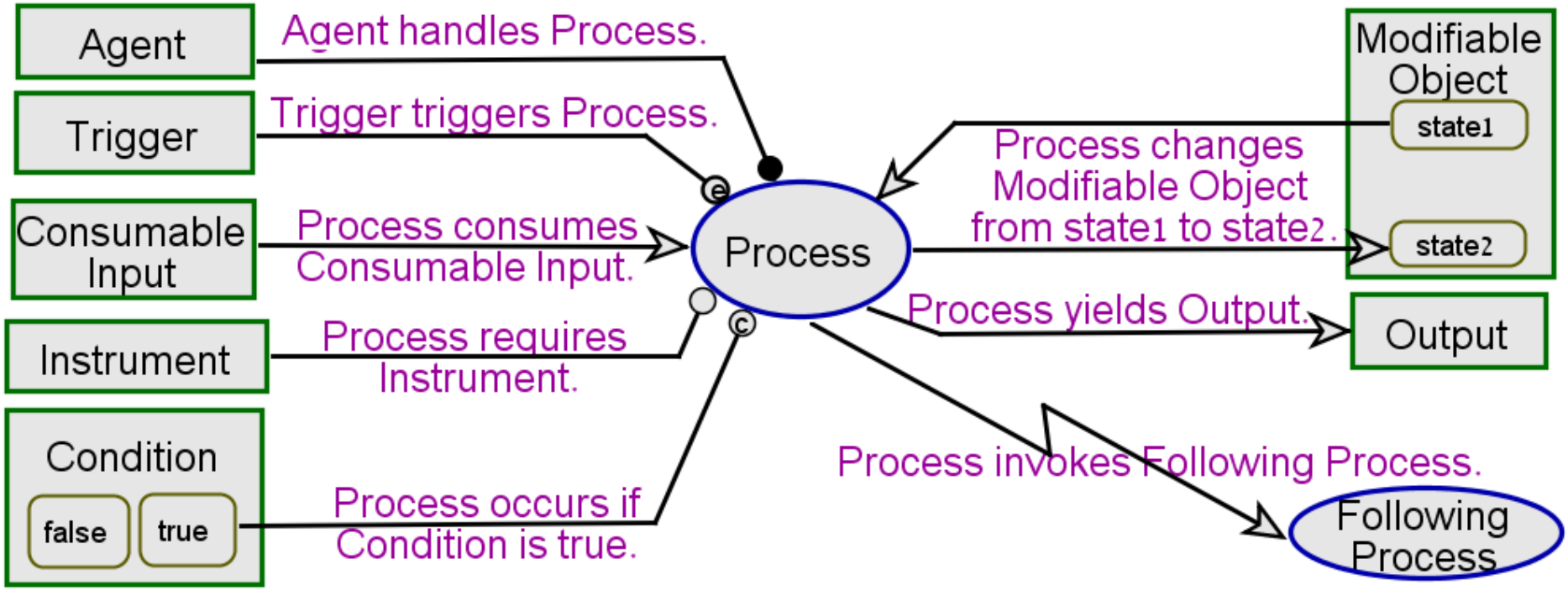
Object-Process Methodology

- A comprehensive systems engineering paradigm with a compact formal language for modeling, communicating, documenting, engineering, and lifecycle support of complex, multi-disciplinary systems.
- Based on simultaneous representation of structure (via stateful objects) and behavior (via processes)
- Bi-modal: the single model is expressed in both graphics and natural language text.

OPM – Structural Relations



OPM Procedural Links



OPM's Benefits for ADM Models

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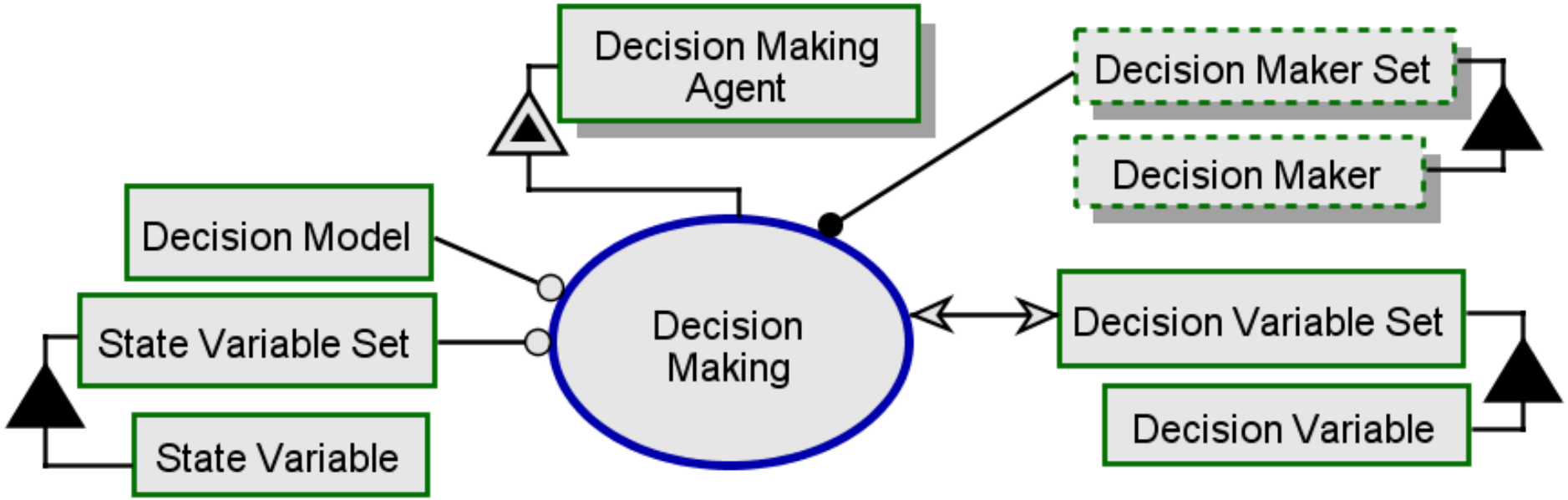
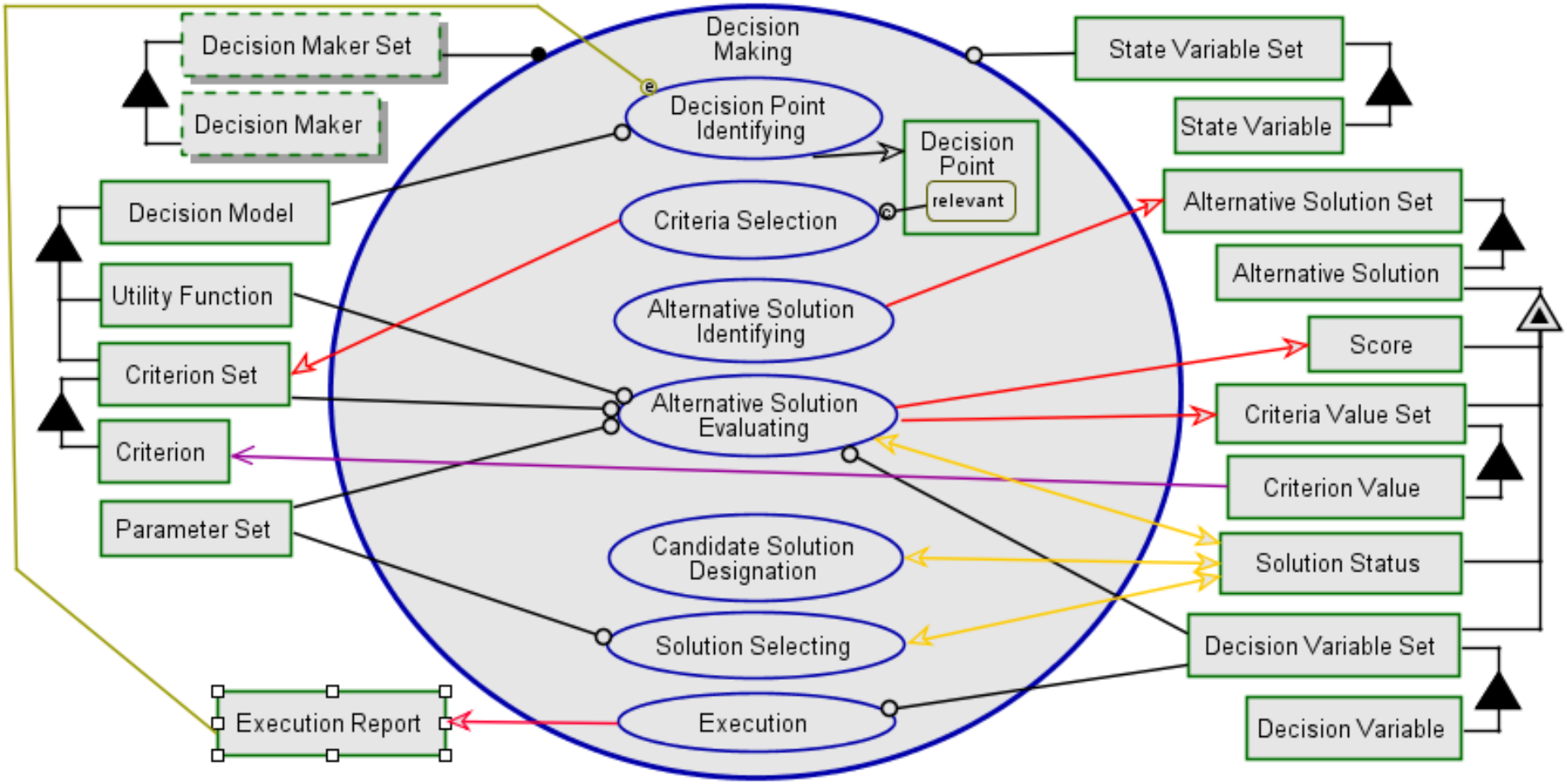
OPM characteristic	Utilization for DM and ADM modeling
Built-in hierarchical decomposition mechanism	Gradual development and extension of the DM model.
Bimodal graphical-textual model representation	Conceptual appeal to both visualists and formalists, catering to the modal preferences of analysts from various backgrounds.
Metamodeling capability	Smooth transition from the generic DM process to the applocation-specific DM problem.
ISO standardization as PAS-19450	Accelerated dissemination and adoption, reinforcing existing design standards with DM concepts.
CASE tool availability	Easy adoption and utilization of the framework, especially in conjunction with existing OPM models; quick migration.

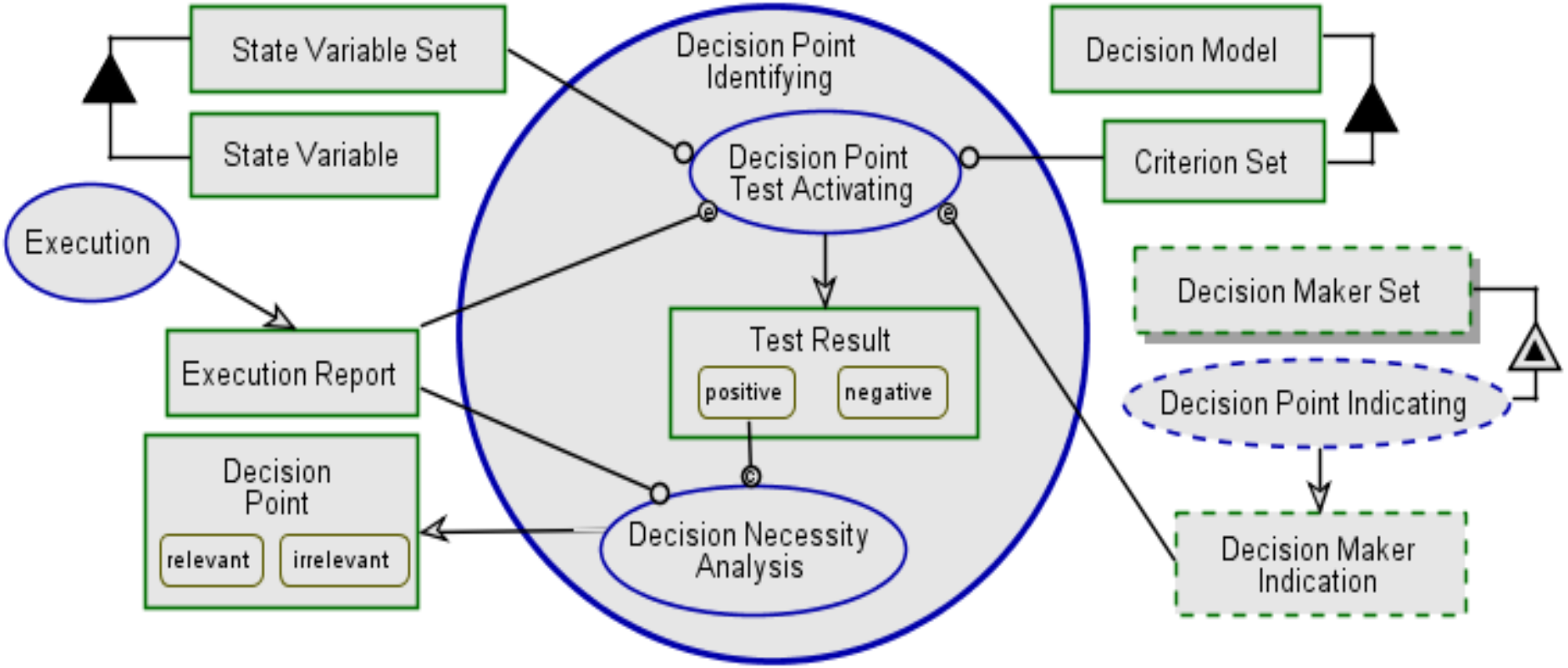
Top-Level Decision Making Process



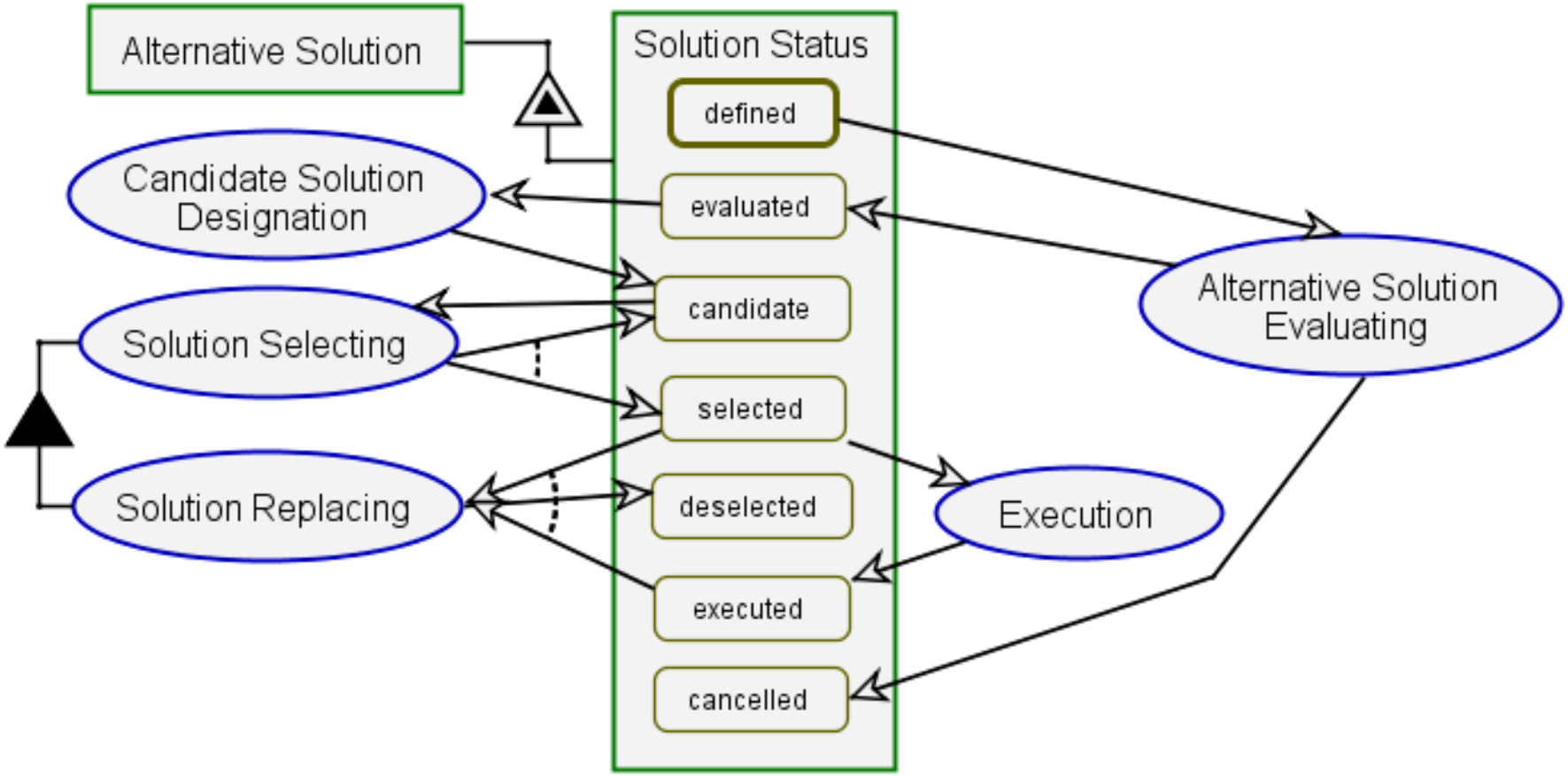
Decision Making – in-zoomed



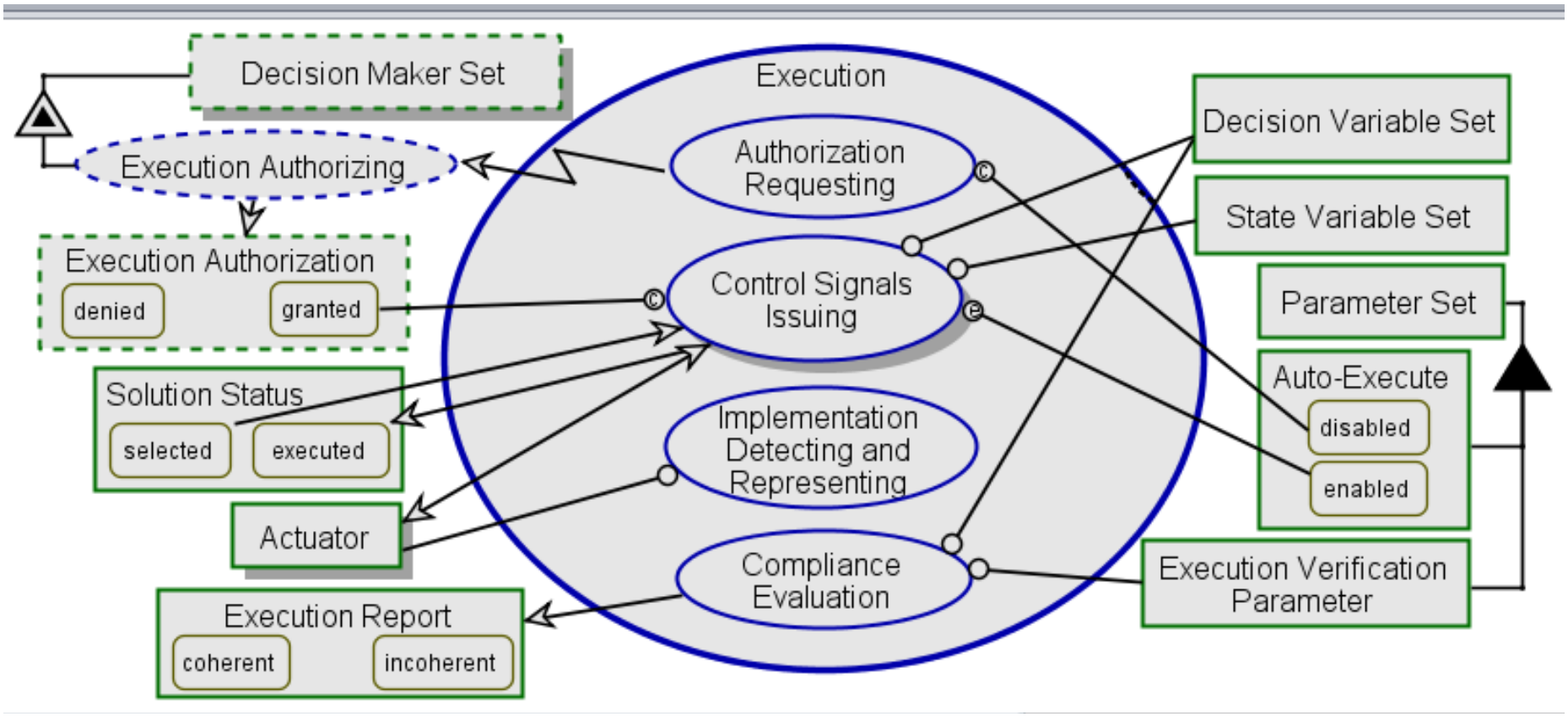
Decision Point Identifying



Solution Lifecycle



Execution


Decision Maker Set
Execution Authorizing
Execution Authorization
denied
granted
Solution Status
selected
executed
Actuator
Execution Report
coherent
incoherent
Execution
Authorization Requesting
Control Signals Issuing
Implementation Detecting and Representing
Compliance Evaluation
Decision Variable Set
State Variable Set
Parameter Set
Auto-Execute
disabled
enabled
Execution Verification Parameter

Summary

- Challenges and gaps in integrated DM system modeling.
- Model-based approach based on OPM for integrating DM and DA process models into system models.
- Future Work:
  - A complete model-based framework for ADM.
  - Applications
  - Integration with complementary framework

Thanks!

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