A Modeling Method to Develop Goal Oriented Adaptive Agents in Modeling and Simulation for Smart Grids

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Outlines

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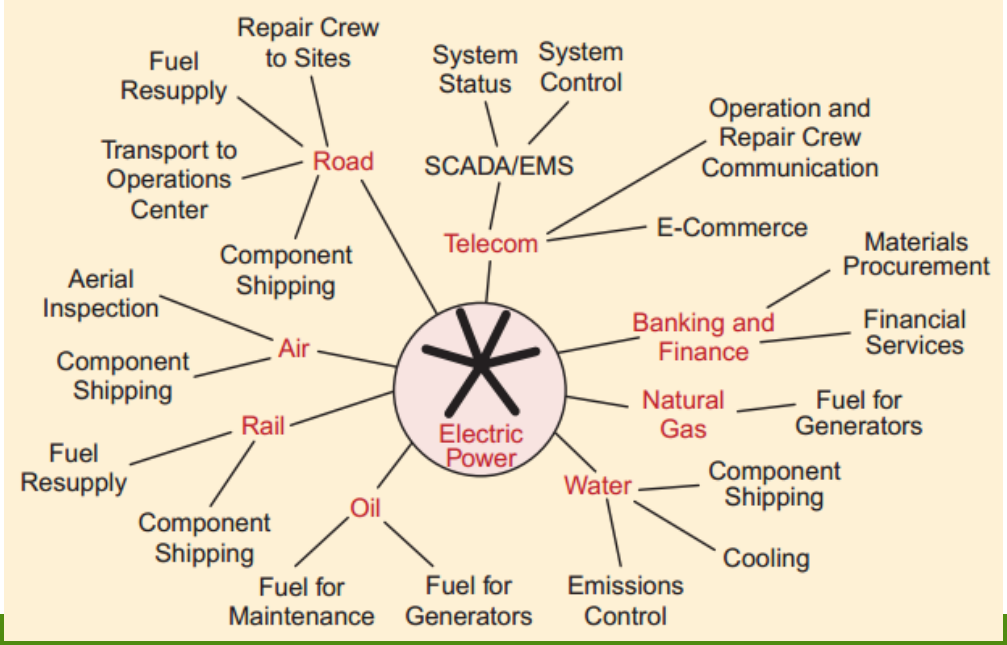
Introduction (1/3)

- Smart Grid is one of **Critical Infrastructures** (CIs), which is highly connected with our life
- The failure of Smart Grid causes considerable risk
- Before applying new policies or requirements, we need to analyze and predict the influences



[Rinaldi, S. M., Peerenboom, J. P., & Kelly, T. K.]

Introduction (2/3)

- **Agent-based Modeling and Simulation (ABMS)** is one of useful approach to analyze and predict a problem in Smart Grid
- Due to **the characteristics of Smart Grid**, it is not an easy task to develop models that satisfy the **Smart Grid requirements**:
  - RQ1> Smart Grid change their behavior dynamically **(Adaptability)**
  - RQ2> Smart Grid evolve as introducing new components or modifying/removing current components **(Evolvement)**
- ABMS can help modeler to make Smart Grid models, but it is **not enough** to achieve two requirements of Smart Grid
- To satisfy these requirements, we need to develop models to be **adaptive** and **evolutionary**

Introduction (3/3)

- We propose a **Goal-oriented ABMS (GoABMS) framework**, which especially focus on the **agent design activity**
- **Concept of goal** help the behavior of an agent to be separated into **means and objective**
- **Goal-oriented Organizational Agents (GOA) model** provide modeler with **traceability** between agents' requirements and their detail design
- As the result, our modeling method enables modelers to design Smart Grid models to be **adaptive** and **evolutionary**

Related Work

- **ABMS for Smart Grid**
  - Karnouskos and Holanda [2], Pipattanasomporn [3], Bou Ghosn et al. [4], Chalkiadakis et al. [5]
  - Do not clearly mention how to design and develop agents
- **Agent-oriented Software Engineering (AOSE)**
  - Gaia [6], Prometheus [7] and Tropos [8]
  - Do not deal with early requirements
  - Rigid architectures
- **Role-oriented Adaptive Design (ROAD)** [9,10]
  - Do not clearly describe the relationship between goal and task

Application Domain

- In order to verify our modeling approach, we adopt a Smart Grid design in **Chalkiadakis et al. [11]**
- The original design is verifying **profit sharing mechanism** for Virtual Power Plant (VPP) and Distributed Energy Resources (DERs)
- In our research, we have three assumptions
  - There are two profit sharing policies: with or without estimated generation
  - Smart Grid has a VPP comprised of several DERs
  - For each DER, the target electricity to be generated is predefined

GoABMS Framework (1/6)

- In GoABMS framework, we especially concentrate on **the design of agents and organizations** derived from the goal-oriented requirements

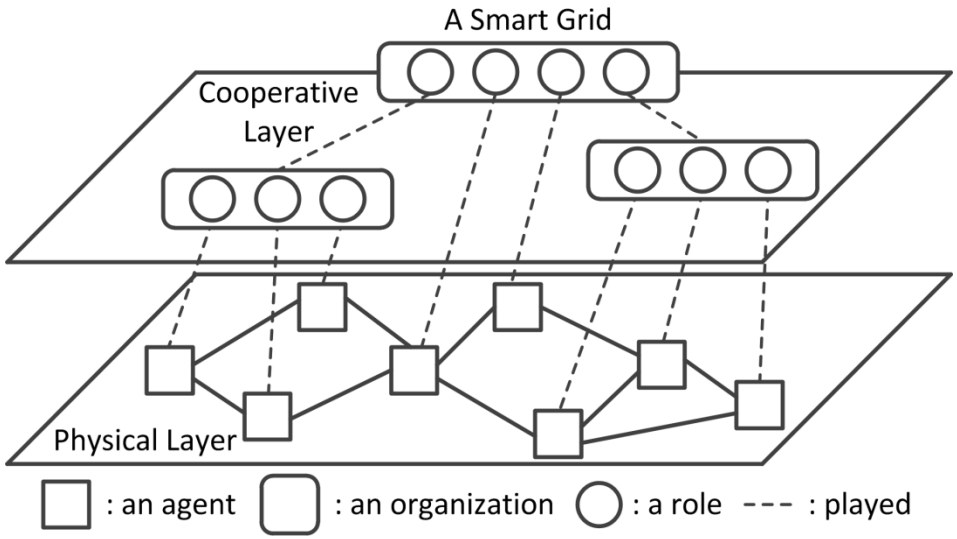


Figure 1. Conceptual model of a smart grid

GoABMS Framework (2/6)

- GoABMS framework has **7 phases** to concretize and design agent model from simulation needs

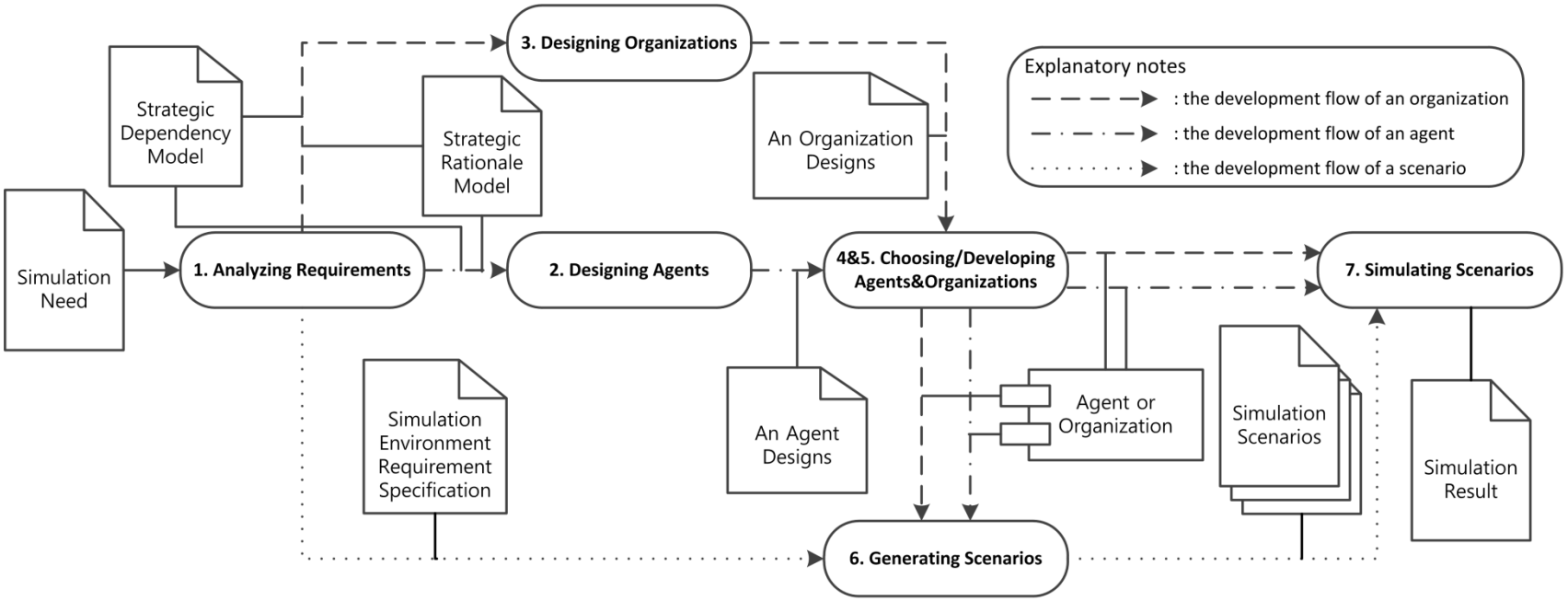


Figure 2. A goal-oriented ABMS framework for smart grids

GoABMS Framework (3/6)

- **Analyzing Requirements**
  - Simulation components and simulation environment are identified
  - Requirements are specified with two types of model: **strategic dependency (SD) model** and **strategic rationale (SR) model**
  - These models describe the dependency between actors and organizations, and the rationale of the actors
- **Designing Agents**
  - Agents are designed in detail from SD and SR models
  - The elements of models are concretized into an agent, goal, action, and context model
  - An agent design includes plans specifying a series of actions to expressing a way for the agents to achieve its goals

GoABMS Framework (4/6)

- **Designing Organizations**
  - Organizations are designed in detail like agents, but difference between agents and organization is actions and roles
  - Instead of actions, **an organization has roles** played by other agents or organization at runtime
  - A role is specified with a set of goals, context model and two conditions
  - For an organization to achieve its goal, plans of the goal are pursued by a goal of roles instead of actions in agent

GoABMS Framework (5/6)

- **Choosing/Developing Agents & Organization**
  - Modeler can choose agents in consideration of the reusability of preexisting agents
  - If a reusable agent does not exist, modelers should develop agents
- **Generating Scenarios**
  - Generating scenarios through setting the initial values and events for simulation environment and agents
- **Simulating Scenarios**
  - A scenarios and agents are combined with a simulation engine and simulation is executed
  - Simulation results are offered to users

GoABMS Framework (6/6)

Phases	Artifacts	Elements	Descriptions
Analyzing Requirements	Simulation Environment Requirement Specification	Electric equipment	Type, amount of the required electricity, etc.
		Weather information	The changes of weather
		Temporal information	The start and end time of simulation
		Spatial information	The range of the simulated world
	Strategic Dependency Model	Dependency type	The relation type between two actors (goal dependency, task dependency, resource dependency, and softgoal dependency)
		Actors	Actors are abstract simulation objects described in the requirements in order to achieve the goal.
	Strategic Rationale Model	Actors' Rationale	The simplified structure to represent the rationale behind the dependency (means-end link, task-decomposition link)
Designing Agents	Agent Design(s)	Goals	Objectives that this agent wants to achieve
		Actions	Tasks that this agent can do in order to achieve the goals
		Context model	Information model for facts that this agent believes
		Plans	Means for this agent to achieves a goal
Designing Organizations	Organization Design(s)	Goals	Objectives that this organization wants to achieve
		Roles	Goals that the role can achieve, context model to specify the belief of the role, and prerequisite and exceptional conditions
		Context model	Information model for facts that this organization believes
		Plans	Means for this organization to achieves a goal
Choosing Agents	Refers to Developing Agents.		
Developing Agents	Agents (or Organizations)	Agent Implementation	Agent implementation that can bind with a simulation framework
Generating Scenarios	Simulation Scenarios	Environment Setting	The simulation environment information (weather, temporal, and spatial information)
		Agents Settings	Initial value for attribute of the agent
		Initial Event List	Planned initial event list for simulation
Simulating Scenarios	Simulation Results	Unconstrained	Not limited because this can be changed by simulation goal

Table 1. Activities and artifacts of GoABMS framework

- Artifacts of previous phase is used in next phase
- Each artifact consist of several elements
- SD and SR model, agent and organization model is most important artifacts in framework

GOA Model (1/3)

- **GOA model is used as a meta-model** able to design and specify adaptive and evolutionary agent and organization models

- **Meta-Model for Agent Requirements**
  - Through GRL of i* framework, actors, intentional elements and intentional relationship is specified
- **Meta-Model for Agent Structure**
  - Specifying how agents or organizations are composed of components
- **Meta-Model for Agent Behavior**
  - Focusing on that every agent can be independently developed with a minimal dependency by other agent

GOA Model (2/3)

- Meta-Model for Agent Structure

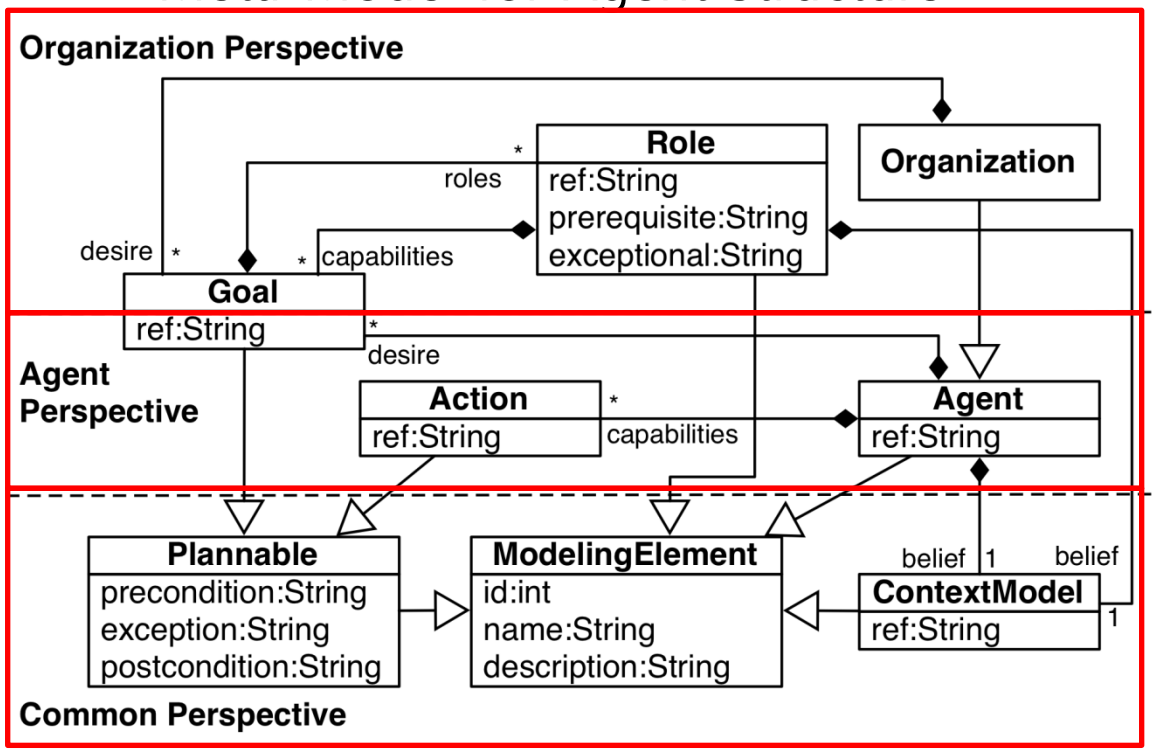


Figure 3. Agent-structural meta-model of GOA model

- Common Perspective
  - Modeling Element
  - Plannable
  - ContextModel
- Agent Perspective
  - Agent
  - Goal
  - Action
- Organization Perspective
  - Organization
  - Goal
  - Role

GOA Model (3/3)

- Meta-Model for Agent Behavior

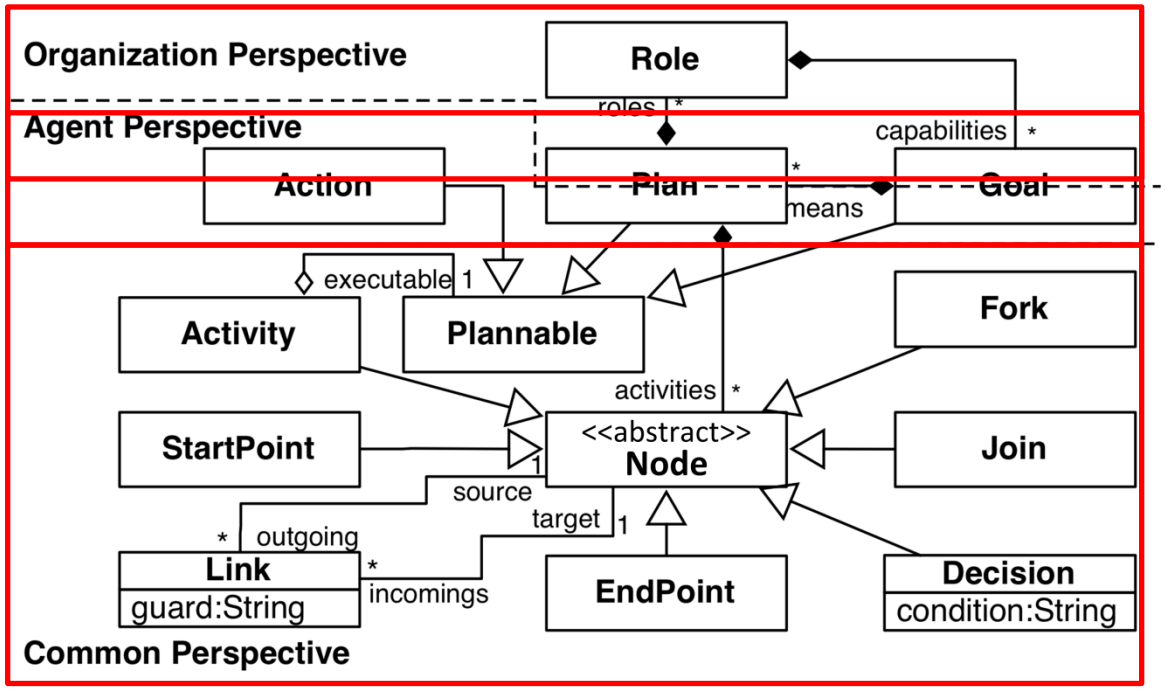
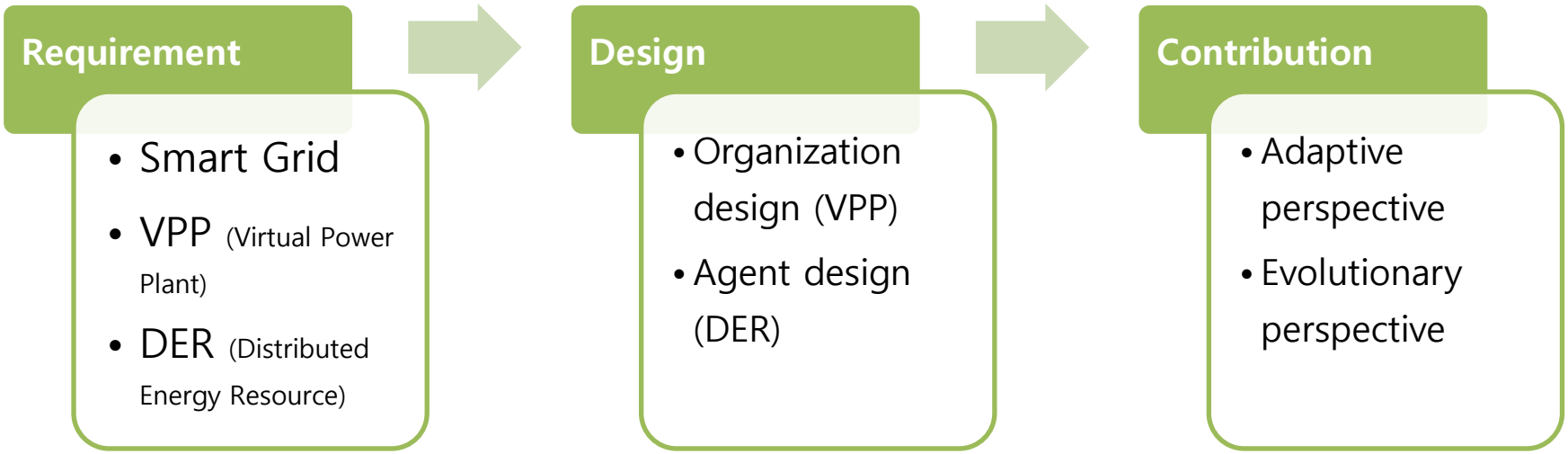


Figure 4. Agent-behavioral meta-model of GOA model

- Common Perspective
  - Node
  - Link
  - StartPoint and EndPoint
  - Fork and Join
  - Decision
  - Activity
  - Plannable
- Agent Perspective
  - Goal
  - Plan
  - Action
- Organization Perspective
  - Goal
  - Plan
  - Role

Case Study (1/4)

- Verify **feasibility** of proposed framework and model
- Focus on **designing agent and organization model** from simulation requirements



Case Study (2/4)

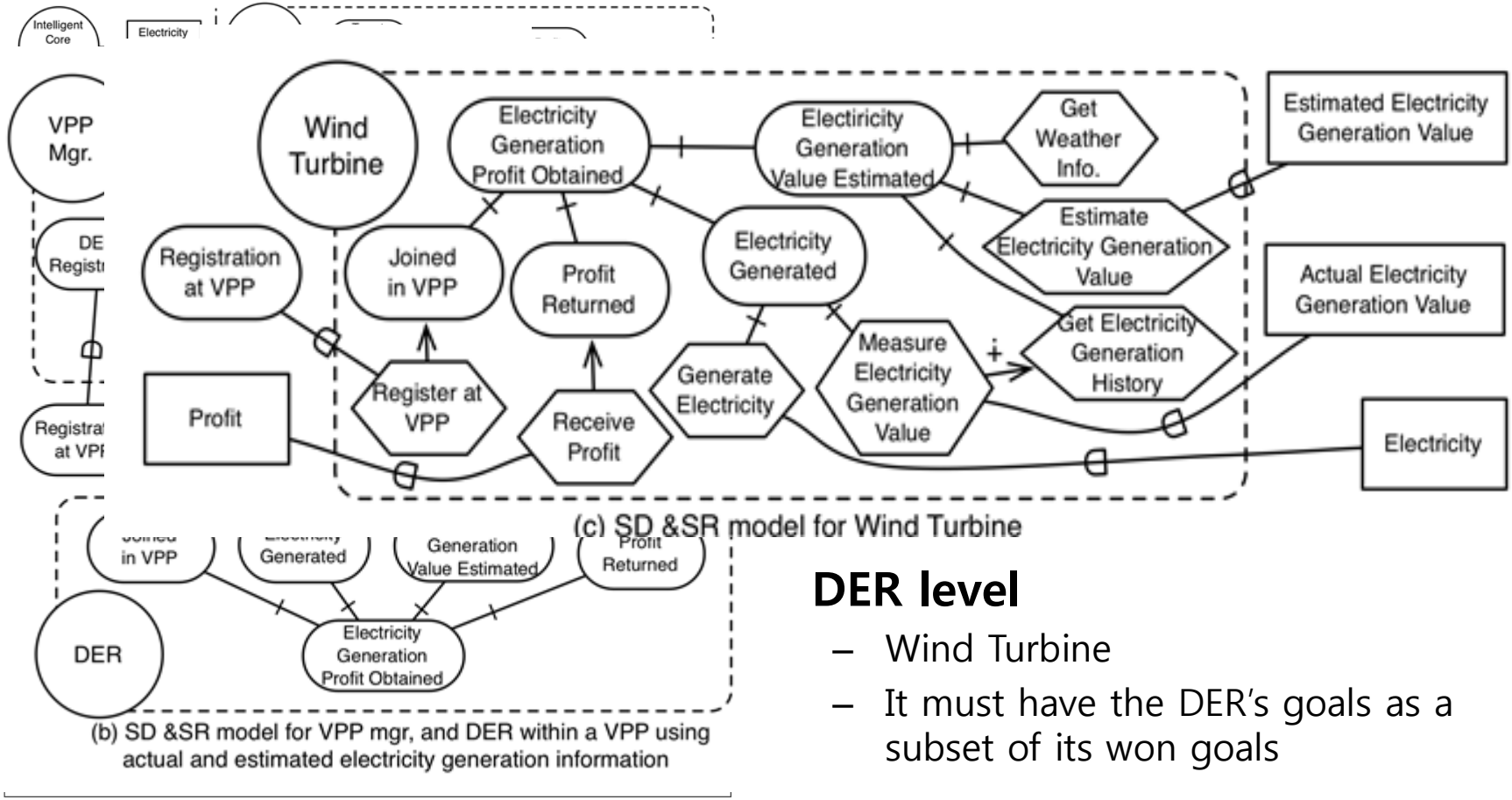


Figure 5. Partial artifacts of analyzing requirements

DER level

- Wind Turbine
- It must have the DER's goals as a subset of its won goals

Case Study (3/4)

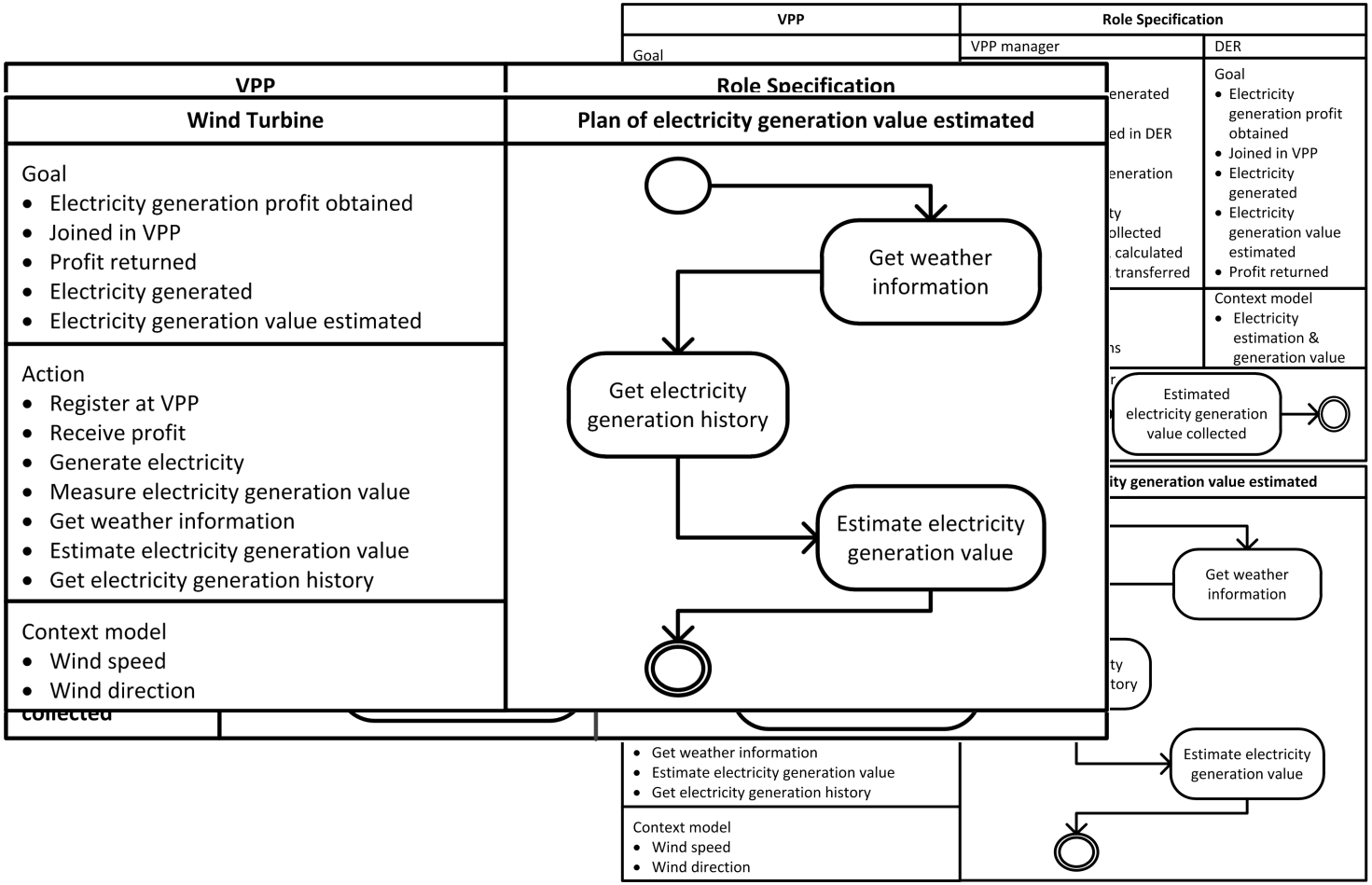


Figure 6. Partial artifacts of designing organization & agent

Case Study (4/4)

- Proposed method has **two perspectives of contribution**: Adaptive and Evolutionary perspective

- **From the adaptive perspective**
  - Structural adaptability
  - Behavioral adaptability

- **From the evolutionary perspective**
  - Introducing new agent
  - Modifying or removing existing agent

Conclusion and Discussion

- We propose a **GoABMS framework** to model and simulate Smart Grid and **GOA model** to design agents and organizations
  - Through GoABMS framework, modeler can design agents for Smart Grid
  - GOA model makes a Smart Grid model more adaptive and evolutionary
  - Case study of profit sharing policies shows the feasibility of proposed method

- As future work, we have a plan to perform further research from various viewpoint
  - Implement simulation system
  - Combine with other techniques
  - Verify through theoretical approach and experiments

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Thank you

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