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

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Outlines

• Introduction
• Related Work
• Application Domain
• GoABMS Framework
• GOA Model
• Case Study
• Conclusion and Discussion
• 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

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.
• 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

![Diagram of GoABMS Framework]

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

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

- 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

Table 1. Activities and artifacts of GoABMS 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
  - Common Perspective
    - Modeling Element
    - Plannable
    - ContextModel
  - Agent Perspective
    - Agent
    - Goal
    - Action
  - Organization Perspective
    - Organization
    - Goal
    - Role

Figure 3. Agent-structural meta-model of GOA model
GOA Model (3/3)

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

Figure 4. Agent-behavioral meta-model of GOA model
Case Study (1/4)

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

**Requirement**
- Smart Grid
- VPP (Virtual Power Plant)
- DER (Distributed Energy Resource)

**Design**
- Organization design (VPP)
- Agent design (DER)

**Contribution**
- Adaptive perspective
- Evolutionary perspective
Case Study (2/4)

- Smart Grid level
  - Intelligent Core, VPP and Consumer
  - SD model to show the relationship between actors

- VPP level
  - VPP manager and DER
  - Following a policy to use information of estimation and generation of electricity

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

Figure 5. Partial artifacts of analyzing requirements
### Case Study (3/4)

#### Organization design
- Represents VPP
- Includes goals, roles, context model, plan for each goal and role

#### Agents design
- Represents Wind Turbine
- Includes goal, action, context model and plan for each goal

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![Diagram](image)

**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
References


Thank you

Q & A