A Roadmap towards Sustainable Self-aware Service Systems

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Our Systems

• Large-scale Systems
  – Decentralized control
  – Continuous change of entities
  – Omnipresence of failures
  – Conflicting interests

• Key characteristics
  – Integration of Humans and Services
  – Sustainable solutions
Autonomic/Self-* Behavior

• Requires awareness about
  – the self and the context
  – the possible adaptation actions
  – effects on current and future goals

Sustainability
Example Problem
Complete Example
Challenges

1. Resource utilization and long-term effects
   – Effects of adaptation actions on long-term resource levels

2. Interdependencies between human and service entities
   – Interleaving structure of humans and services throughout organizations

3. Limited view on local information
   – Entities only see changes in joint activities

4. Dynamic evolution of the whole system (requirements, interests, topology)
   – Changes in one part of the system may have effects on the fulfillment of goals on another system’s segment

5. No central adaptation authority
   – Adaptation actions need to be carried out in a joint fashion
## Levels of Awareness

<table>
<thead>
<tr>
<th>Levels of Awareness</th>
<th>Principles</th>
<th>Models</th>
<th>Algorithms</th>
<th>Protocols</th>
</tr>
</thead>
<tbody>
<tr>
<td>Event Awareness</td>
<td>• Adaptation based on event and conditions; unaware of resources</td>
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<tr>
<td>Situation Awareness</td>
<td>• Ability to embed simple events in a larger context</td>
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<tr>
<td>Adaptability Awareness</td>
<td>• Engage in cooperative adaptation based on information about the collective adaptation actions</td>
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<tr>
<td>Goal Awareness</td>
<td>• Ability to make trade-offs between an entity’s goal and environmental constraints</td>
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<tr>
<td>Future Awareness</td>
<td>• Ability to reason on probable future resource levels</td>
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Event Awareness

• Description of single events
  – Basic source of information about the self
• Dynamic boundaries between context and self
  – Dynamic aggregations cause scope changes for context and self
• Data filtering and dissemination
  – Self-organizing algorithms for managing models and data

• Addressed Challenges:
  ++ 2) Understanding interdependencies
  + 3) Limited local view on information
  + 4) Dynamic evolution
Situation Awareness

• Fuzzy models and granular information
  – Good/Accurate enough context and self
• Activity patterns
  – Reoccurring events, correlation of events
• Coordination of information distribution based on relevance
  – Distribute and agree upon high-level situations (filtering out irrelevant situations)

• Addressed Challenges:
  ++ 2) Understanding interdependencies
  ++ 3) Limited local view on information
  + 4) Dynamic evolution
  + 5) No central adaptation
Adaptability Awareness

- Adaptation Capabilities
  - Describe entities’ willingness and ability to adapt
- Verification of entity compositions
  - Describe and determine whether a composition of entities is able to adapt as required
- Coordination and Control Protocols
  - Distributed agreement on and enforcement of adaptation actions

- Addressed Challenges:
  ++ 2) Understanding interdependencies
  + 3) Limited local view on information
  + 5) No central adaptation
Goal Awareness

• Goal Modeling
  – Linking high-level goals to low-level constraints and actions
• Goal Violation and Satisfiability
  – Decentralized monitoring of goals for probabilistic goal satisfaction
• Trade-off Analysis
  – Determining which goals can/cannot be achieved
  – Evaluate the effect of pursuing of one goal on other goals
• Goal dissemination
  – Dynamic updating of goal models and constraints across the system

• Addressed Challenges:
  ++ 1) Resource utilization and effects
  + 3) Limited local view on information
  ++ 4) Dynamic evolution
  + 5) No central adaptation
Future Awareness

• Sustainability
  – Fulfill current goals without compromising future goals
• Resource Life-cycle Model
  – Effects of actions on draining/replenishing resources
• Probabilistic reasoning
  – Correlation of life-cycle model with observed activity patterns
  – Learning from past behavior in large-scale environment
• Knowledge dissemination
  – Effective sharing of low-level learning data and high-level predictions

• Addressed Challenges:
  ++ 1) Resource utilization and effects
  + 3) Limited local view on information
  + 4) Dynamic evolution
  + 5) No central adaptation
Service System Maturity

- Sustainability
  - Event
  - Situation
  - Adaptability
  - Goal
  - Future

- Context-dependent Actions
- 1-to-1 mapping Action - Resource
- Self-adjusting Resource Utilization
- Resource Goal Trade-off
- Predictive Resource Utilization

Levels of Awareness
Conclusions and Future Work

• This is our roadmap to sustainable self-aware service systems

• Our view is only one of the possible options to address all these issues
  – Many different solutions can be identified for the different parts

• The future of this roadmap is …