Dynamic Context Management and Reference Models for Dynamic Self-Adaptation

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Fundamental Concepts

- **Software System**: Operates in Context and Affects Situation-Aware
- **Requirements**: Satisfies Software System
- **Context**: Operating in Uncertainty and Changes at runtime
- **Situation-Aware**: Understands context and Adjusts itself
- **Self-Adaptive**: Adjusts itself and Changes at runtime
- **Uncertainty**: Change at runtime
Fundamental Concepts

Situation-aware smart software (SASS) system
Problem Statement

To maintain the relevance of situation-awareness, with respect to changing requirements and context situations, to improve user QoE and self-adaptivity
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To maintain the relevance of situation-awareness, with respect to changing requirements and context situations, to improve user QoE and **self-adaptivity**
Selected Research Challenges

CH1: Complete specification of context is impractical at design time (uncertainty)

CH2: Context monitoring infrastructures must be self-adaptive and user-driven

CH3: The need for reference models for self-adaptation that address dynamicity at all levels
CONTRIBUTIONS ON DYNAMIC CONTEXT MANAGEMENT
Uncertainty in Self-Adaptation
Necessity of Dynamic Context Management

Effectiveness of Self-adaptation depends on dynamic capabilities of monitoring mechanisms to preserve context-awareness throughout the adaptation process.

Monitoring requirements evolve over time due to uncertainty.
Contributions (1): The SMARTERCONTEXT Ontology and Context Spheres

Our semantic web solution to context modeling

• Modeling support for:
  – Context entities and their relationships
  – Context reasoning rules
  – Context monitoring requirements
  – Privacy policies

• Adaptable at runtime

• Fully extensible

• Empowers users as context managers

Villegas and Müller: The SmarterContext Ontology and its Application to the Smart Internet: A Smarter Commerce Case Study. (Springer 2013)
Contributions (2): The SmarterContext Reasoning Engine

Efficient context inference with extensible and adaptive reasoning rules

Villegas and Müller: The SmarterContext Ontology and its Application to the Smart Internet: A Smarter Commerce Case Study. (Springer 2013)
Contributions (3): The SMARTERCONTEXT Infrastructure

- Realizes dynamic context management across the context life cycle
- Adaptive monitoring logic
- Adaptive monitoring architecture


To apply user-centric dynamic context management to improve user QoE

Evaluation: Situation-Aware Smarter Shopping

- Qualitative evaluation
  - Potential to enable new e-commerce business models
  - Applicability

- Quantitative evaluation
  - Effectiveness (accuracy of recommendations)
  - Efficiency (reasoning engine)

Four software prototypes
(SURPRISE, SMARTERCONTEXT engine, SMARTERCONTEXT infrastructure for shopping, SMARTERDEALS)
CONTRIBUTIONS ON REFERENCE MODELS FOR DYNAMIC SELF-ADAPTATION

- Three levels of dynamicity
- Specific interactions clearly defined
- Goal: maintain context monitoring relevance


Case Study: Znn.com

SLA QF1: Throughput (ms/request)

Our DYNAMICO Implementation
(QoS-CARE + SmarterContext)

The Target System
(response time and contents quality)
Case Study: Znn.com

Our DYNAMICO Implementation
(QoS-CARE + SmarterContext)

The Target System
(response time and contents quality)

SLA QF1: Throughput (ms/request)

SLA QF2: Capacity (text or multimedia according to bandwidth)

Context:
- bandwidth up/down
- ms/request

Text-based Contents

Znn.com
DYNAMICO: An Implementation (1)

- Hierarchical feedback-loops
- Context as a knowledge source
- Maintains context relevance wrt control objectives
DYNAMICO: An Implementation (2)

• Monitor probes, gatherers, and processors dynamically deployed
Evaluation

• Goal: To evaluate DYNAMICO’s applicability and effectiveness

• Evaluation Scenario: based on the SEAMS’s Rainbow/Znn.com reference exemplar

• Criteria:

  - Engineering Effort (man hours to add self-adaptive capabilities)
  - Performance (settling time and processing overhead)
  - Effectiveness (QoS preservation under changing contexts)
Evaluation Results (1)

Engineering Effort (man hours)

Evaluation Results (2)

Performance (settling-time)

Target System Adaptation

0 200 400 600 800 1000 1200

DYNAMICO  Rainbow
## Evaluation Results (3)

### Performance (settling-time and overhead)

<table>
<thead>
<tr>
<th>DYNAMICO: Monitoring Infrastructure Adaptation</th>
<th>SLA 1 (msec)</th>
<th>SLA 2 (msec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>CO-FL (Analyzing changes in goals)</td>
<td>698</td>
<td>732</td>
</tr>
<tr>
<td>M-FL (Analyzing the new monitoring strategy)</td>
<td>21</td>
<td>29</td>
</tr>
<tr>
<td>A-FL (Implementing the new monitoring strategy)</td>
<td>1,131</td>
<td>1,579</td>
</tr>
<tr>
<td><strong>Total MTTR</strong>*</td>
<td><strong>1,850</strong></td>
<td><strong>2,340</strong></td>
</tr>
<tr>
<td>Target System Overhead</td>
<td>3</td>
<td>3</td>
</tr>
</tbody>
</table>

* Mean time to reconfigure
Evaluation Results (4)

Effectiveness (QoS Preservation under changing contexts)

Adapting the Monitoring Infrastructure is a Key Factor to Maintain Context Relevance and Self-Adaptation Effectiveness
ONGOING AND FUTURE WORK
On Dynamic Context Management

- Monitors and Analyzers that exploit predictive analytics
- Uncertainty management through viability zones
- Industrial validation of SmarterContext in the e-commerce domain (for user-centric systems)
- Further development of the SmarterContext framework
On Reference Models and Models at Runtime for Self-Adaptation

• Runtime models for the assurance of self-adaptive systems at the three levels:
  – Objectives: requirements specifications
  – Adaptation: states of the managed system
  – Monitoring: context entities, monitoring requirements and strategies

• Runtime interactions among these models (causally connected)

• Runtime models for the management of viability zones
On Exemplars and Evaluation Frameworks
Ideal exemplars: based on the spectrum of adaptation strategies

Znn.com is a good starting point. However, we need more versatile exemplars and evaluation frameworks.

Adaptation Dimension 2: Managed System’s Structure

<table>
<thead>
<tr>
<th>Non-modifiable structure</th>
<th>Modifiable structure</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Software models and reflection</td>
</tr>
</tbody>
</table>

Selected Publications

• Norha Villegas’s Dissertation: [http://dspace.library.uvic.ca:8080/handle/1828/4476](http://dspace.library.uvic.ca:8080/handle/1828/4476)