Using Semantic Web Technology for Self-Management of Distributed Systems

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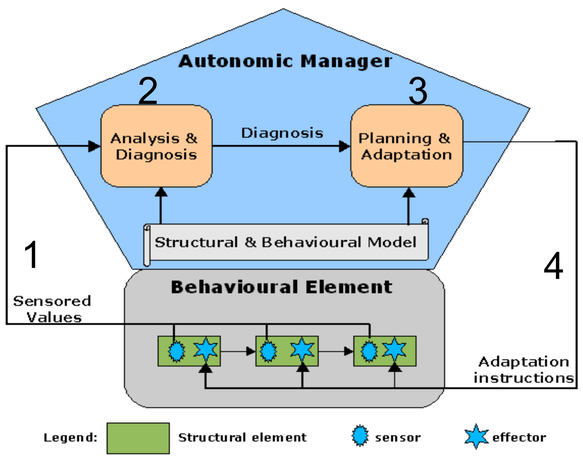
1. Self-Management

Maintenance and configuration becomes more difficult as systems are increasingly more complex, with multiple distributed components → *systems should manage themselves: self-management*



Self-Management feed-back loop

1. Sensors in the managed unit are triggered
2. Autonomic manager *analyses* sensored values and determines a *diagnosis*
3. Autonomic manager makes a remedy *plan*
4. Effectors implement adaptation instructions

2. Self-Management Knowledge

Self-management knowledge is modelled as follows:

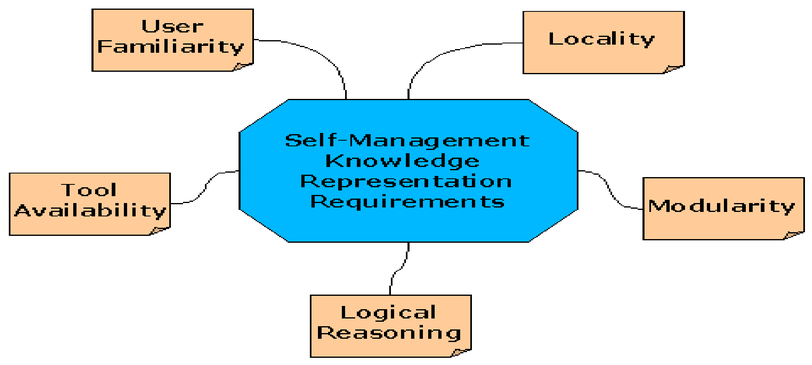
- **Static model** – describes the structure of the system (systems, runnables, components, etc.).
- **Dynamic model** – describes the correct behaviour of the system, based on use-cases.
- **Management model** – describes reasoning rules, symptoms of misbehaviour, diagnoses, sensors, etc.

Problem
Which language to use for representing Self-Management Knowledge?

Approach
Use Semantic Web languages:
- OWL for expressing self-management concepts, their relationships, and constraints
- SWRL for expressing analysis and diagnostic rules, and policies

3. Requirements for the Representation of Self-Management Knowledge

- **Reasoning** – The representation must support logical rules to reason about concepts in the models.
- **Distributed knowledge** – In a distributed environment, the representation needs support for reasoning with distributed entities.
- **Usability** – a) Choose a representation that is familiar to the people supplying the self-management knowledge: *system administrators, functional analysts, and system developers.* b) The availability of tools to develop models (automatic syntax & constraints checks, IDEs, etc.) will increase its acceptance.



4. Semantic Web Satisfies these Requirements

Characteristics of the Semantic Web languages OWL+SWRL:

- **Reasoning** - Rules can be expressed in SWRL, which is closely integrated with OWL: rules can directly refer to OWL-concepts.
- **Distributed knowledge** - Support for *Uniform Resource Identifiers* (*URI*) that can identify and refer to resources stored on distributed locations.
- **Usability** – a) OWL has common and relevant features with UML, the de-facto standard in software development. The relationship between OWL and UML is officially described in the *Ontology Definition Metamodel* (*ODM*) specification. b) The Semantic Web community provides various tools and techniques for checking syntax and consistency of OWL documents (e.g., Protégé).

5. Example Scenario: Simplified Trading Application

This simplified distributed trading application (simplifiedTrading) is borrowed from Fortis Bank, Netherlands.

- Multiple (distributed) OWL-documents describe the *static*, *dynamic*, and *management model* of the self-managed system.
- **Static model:** SimplifiedTrading is a composite system, containing a runnable (webApp), which has a component (paymentComp), which has one class (tradeCls).
- **Dynamic model:** The monitored use-case is sendPayment.
- **Management model:**
  - The Sensor amountSensor monitors the variable amount in tradeCls.
  - Analyser raises the symptom lowAmountSymptom when the SWRL rule matches (lowAmountSymptomrule).

static-model ontology - structure of application

```
<System rdf:ID="simplifiedTrading">
   <hasSubElement rdf:resource="#webApp"/>
</System>
<Runnable rdf:ID="webApp">
   <hasSubElement rdf:resource="#paymentComp"/>
</Runnable>
<Component rdf:ID="paymentComp">
   <hasSubElement rdf:resource="#tradeCls"/>
</Component>
<Class rdf:ID="tradeCls">
   <hasManagedElementState
      rdf:resource="dynamic-model#amount"/>
</Class>
```

dynamic-model ontology - use-case describing behaviour of system

```
<Job rdf:ID="sendPayment">
   <hasTask rdf:resource="#amountManipulation"/>
   <hasSymptom rdf:resource="analyser#lowAmountSymptom"/>
</Job>
<Task rdf:ID="amountManipulation">
   <manipulatedState rdf:resource="#amount"/>
   <executesWithin rdf:resource="static-model#tradeCls"/>
   <monitoredBy rdf:resource="sensor#amountSensor"/>
</Task>
<ClassState rdf:ID="amount">
   <hasStateType rdf:resource="#doubleType"/>
</ClassState>
```

sensor ontology – one sensor monitoring a value

```
<ClassStateSensor rdf:ID="amountSensor">
   <monitorsItem rdf:resource="dynamic-model#amount"/>
   <observedValue rdf:datatype="xsd#double">0</observedValue>
</ClassStateSensor>
```

analyser ontology – analyse when something is wrong

```
<Analyser rdf:ID="tradeAnalyser">
   <analysesJob rdf:resource="dynamic-model#sendPayment"/>
   <determinesSymptom rdf:resource="#lowAmountSymptom"/>
</Analyser>
<Symptom rdf:ID="lowAmountSymptom">
   <requiresSensor rdf:resource="sensor#amountSensor"/>
   <swrl:Imp rdf:ID="lowAmountSymptomRule">
      observedValue(amountSensor, ?x) /\
      swrlb:lessThan(?x, 20.0) →
      hasArisen(lowAmountSymptom, true)
   </swrl:Imp>
</Symptom>
```

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