Self-Adaptive/Autonomic Systems

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Self-Adaptive/Autonomic Systems

• **Definition [Salehie09]:** “Self-Adaptive software evaluates its own behavior and changes behavior when the evaluation indicates it is not accomplishing what it is intended to do, or when better functionality or performance is possible”.

• **Motivation:** system complexity!
  
  In 2010, around 200 million IT workers will be required to keep computer systems running.
Self-Properties

• From [IBM01]:
  – Self-awareness,
  – Self-configuring,
  – Self-protecting,
  – Self-Optimizing,
  – Self-healing,
  – Self-adapting,
  – Etc…
Hierarchy of Self-Properties

- Self-Adaptiveness
  - Self-Configuring
  - Self-Optimizing
  - Self-Awareness
- Self-Protecting
  - Self-Healing
  - Context-Awareness
Feedback Loop

- **Sensors:**
  - Observing the system.
- **Effectors:**
  - Acting on the System.
- **Analyzing:**
  - Some model of the system.
Examples of Work

• Automatic Modelisation:
  – Diagnosis

• Automatic Analysis:
  – Control
Model Bootstrapping for Automated Diagnosis
Outline

• Context and Problem
• Automatic Model Generation
  – Learning from data
  – Issues
• Results
Link with Self-adaptation

Analysis = Diagnosis

- Collect Data
- Analyze Data
- Act

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Model: Bayesian Networks

- **P(P=L)** = 0.90
- **P(S=T)** = 0.30
- **P(C=T|P,S)**
  - H T = 0.05
  - H F = 0.02
  - L T = 0.03
  - L F = 0.001

**C P(X=pos|C)**
- T = 0.90
- F = 0.20

**C P(D=T|C)**
- T = 0.65
- F = 0.30
Log Files

Thu Sep 20 22:57:52 2007 [notice] HTTP Server Powered by Apache/1.3.19 configured -- resuming normal operations
Thu Sep 20 23:06:35 2007 [error] OPM: Can not find one alive process
Thu Sep 20 23:14:55 2007 [error] OPM: Can not find one alive process
Thu Sep 20 23:14:55 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Thu Sep 20 23:14:55 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 00:45:45 2007 [error] OPM: Can not find one alive process
Fri Sep 21 00:45:45 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 00:53:51 2007 [error] OPM: Can not find one alive process
Fri Sep 21 00:53:51 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 01:05:21 2007 [error] OPM: Can not find one alive process
Fri Sep 21 01:05:21 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 02:47:49 2007 [error] OPM: Can not find one alive process
Fri Sep 21 02:47:49 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 04:23:17 2007 [error] OPM: Can not find one alive process
Fri Sep 21 04:23:17 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 05:52:19 2007 [error] OPM: Can not find one alive process
Fri Sep 21 05:52:19 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 06:27:19 2007 [error] OPM: Can not find one alive process
Fri Sep 21 06:27:19 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 08:42:55 2007 [error] OPM: Can not find one alive process
Fri Sep 21 08:42:55 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 11:06:16 2007 [error] OPM: Can not find one alive process
Fri Sep 21 11:06:16 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 11:07:37 2007 [error] OPM: Can not find one alive process
Fri Sep 21 11:07:37 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 12:43:53 2007 [error] OPM: Can not find one alive process
Fri Sep 21 12:43:53 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 12:46:54 2007 [error] OPM: Can not find one alive process
Fri Sep 21 12:46:54 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 13:58:19 2007 [error] OPM: Can not find one alive process
Fri Sep 21 13:58:19 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 14:51:11 2007 [error] OPM: Can not find one alive process
Fri Sep 21 14:51:11 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 16:10:51 2007 [error] OPM: Can not find one alive process
Fri Sep 21 16:10:51 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 16:56:16 2007 [error] OPM: Can not find one alive process
Fri Sep 21 16:56:16 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Fri Sep 21 18:45:18 2007 [error] OPM: Can not find one alive process
Fri Sep 21 18:45:18 2007 [error] [client IP ADDRESS] File does not exist: /discoverer4i/viewer
Model: Bayesian Networks
Fault Injection

- No code modification.
- Configuration files modification.
- Trade-off between Diagnostics Expertise and Engineering Expertise.
- 15 faults injected over 5 weeks.
- Bayesian Network generated: 42 variables including 15 targeted issues.
### Results

- **Reference Network:** 213 nodes and 59 targeted issues
- **Generated Network:** 42 nodes and 15 targeted issues

<table>
<thead>
<tr>
<th>Description</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of issues targeted by the model</td>
<td>15</td>
</tr>
<tr>
<td>% of issues targeted by the model w.r.t the reference BN</td>
<td>25.4</td>
</tr>
<tr>
<td>Number of observations/nodes also present in the reference BN</td>
<td>17</td>
</tr>
<tr>
<td>% of observations/nodes in the generated model also present in the reference BN</td>
<td>13.3</td>
</tr>
<tr>
<td>Total % of nodes in the generated model w.r.t the reference BN</td>
<td>15</td>
</tr>
</tbody>
</table>
Discussion

- Structural relevance: 15% of the overall number of nodes in the network with 25% of the targeted issues.
- Functional relevance: 5 issues out of 15.
- Some relevant type of observations were introduced (3 issues).
Automatic Control of Communicating Components
Link with Self-adaptation

Analysis = Control

Collect Data

Analyze Data

Act
Finite State Machine Example

G

failure

end1 act1

failure act2 end2
Control of FSM

System

Control Objective

G

K

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Supervisory Control Problem (BSCP)

- Events are either controllable ($A_c$) or uncontrollable ($A_u$).
- **BSCP**: compute a maximal $S$ satisfying the objective.
- Supervised System $S/G$: Controllability
  \[(S/G).A_u \cap G \subseteq S/G\]
  and optimality.
Event **failure** is uncontrollable!
Supervisory Control Theory

- Ramadge and Wonham (1982).
- BSCP on a Monolithic Systems (one FSM).
- Non Blocking Control (NBSCP).
- Modular Control (several Control Objectives).
- Partial Observation.
- Decentralized Control.
- Control of Concurrent Systems.
Concurrent System Example

G1

G2
Composition Example

G1

G2

G1 \parallel G2
Supervisory Control on Concurrent Systems

- Supervisor $S_i$ only observes and acts on $G_i$.
- **Theorem** [W&H]: A solution exists iff the objective is separable, i.e. $K = K_1 \parallel K_2$
- No global objective can be ensured.
Desynchronized Systems

- Consider a different mode of composition.
- Input/output event systems.
- Output events are broadcasted.
- Robust to receiving events.
Example

• Output Events:
  Data_sent1, idle1, timeout

• Input Events:
  idle2, stop_process
Example

G₁:
- States: idle1, idle2, stop_process
- Transitions: data_sent1, idle1, timeout

G₂:
- States: idle1, idle2, data_sent2
- Transitions: data_sent1, idle2, timeout, idle1
Semi-Parallel Composition

$G_1 \parallel G_2$
Results

Theorem: If

- An output can be sent by at most one component,
- An input is expected by one of the components, then it can always be sent by the relevant one,
- The objective is “consistent”,

Then

It exists a solution to the BSCP following a distributed architecture (and we know an algorithm to compute it).
Challenges

• Bridging the gap between Formal Methods and system real system models.

• Automate the whole process:
  – Model obtained from code.
  – Automatic computation of a supervisor.
  – Application driven by the supervisor.
Thank You!