Intrinsic Flexibility and Robustness in Adaptive Systems: A Conceptual Framework

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July 25th, SMCals/06, Logan, Utah
Outline

1. Introduction
   - Motivation
   - Objectives

2. The Plan
   - Version Control Systems
   - Reconfiguration in Hardware
   - The Conceptual Framework

3. The Outcome
   - New System Properties
   - Preliminary Results
   - Target Applications/Challenges

4. Summary
Flexibility, Robustness, and Performance

- Performance increases with specialization
- Robustness increases with generalization
- Performance and robustness are opposite
- Archetype nature: achieve high fitness & exploit a niche at best ⇒ But why became the dinosaurs extinct?
Introduction

Objectives

Goals

1. Get along with uncertainty in technical systems
2. Performance in dynamic environs ⇒ need for adaptability
3. Robustness in case of failure or abrupt changes

Conclusion: We need mechanisms to specialize and to generalize!
Source of Inspiration: CVS

1970  SCCS - diffing function

1985  RCS - multiple but exclusive users

1990  CVS - multiple simultaneous users

200x  Subversion, monotone...

CVS is well known, approved, and widely used
**Source of Inspiration: CVS**

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CVS is well known, approved, and widely used
Why is CVS interesting for our goals?

<table>
<thead>
<tr>
<th>Feature</th>
<th>in CVS</th>
<th>in the Framework</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Version Numbering</strong></td>
<td>Distinguish changes and different releases</td>
<td>Temporal order, incremental logging</td>
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<tr>
<td><strong>Branching</strong></td>
<td>Isolate changes for separate lines of development</td>
<td>Adaptation in different directions</td>
</tr>
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<td><strong>Role-back</strong></td>
<td>Go back to main line of development</td>
<td>Memory, checkout of former revisions</td>
</tr>
<tr>
<td><strong>Multiple users</strong></td>
<td>Concurrent editing</td>
<td>Redundancy</td>
</tr>
</tbody>
</table>

⇒ Rich set of available features
Adaptation in Hardware: FPGAs

- Rich in logic resources & features
- Wired during Synthesis-Flow
- Partial Dynamic Reconfiguration (PDR)
Reconfiguration in Hardware

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PDR

- Reconfigure distinct parts @ runtime
- Increased flexibility
- In-field updates & bug-fixes
- Applications allowing no interrupts
- Self-x attributes
Managing all this: Operating System Support

- No new OS ⇒ modify existing one
- Linux is Open Source
- Modifications to support dynamic reconfiguration in hardware and software
- hardware resources managed like memory ⇒ going virtual
- Existing CVS features can be used
The Conceptual Framework

Overview

The new conceptual Framework

1. System context to be tracked & stored in a CVS library
2. System’s own specification
3. Redundant system models allow for adaptation
4. System-wide observer
5. Coordination by meanings of a modified Linux operating system
**The System Context**

- Triplet of information
  - Current input patterns to recognize certain conditions
  - Internal configuration parameters
  - Timestamp as index

**The System Specification**

- System’s own functional scope, parameters, and constraints
- Policies for specialization and adaptation mechanisms
System Context in a CVS

- ... stored on occurrence of changes
- Version no. & timestamp ⇒ temporal order
- Represents lifecycle and knowledge base
- Estimate future or cyclic events
- Proactive preparations ⇒ proprioception
- System’s history affects its future
- Obsolete entries may be deleted
Adaptation requires Redundancy

- Two concurrent system models
- Flexible shift work in a loop
- 2 Shifts
  - Analyze & Plan
  - Monitor & Execute
- Human sleep: Awake ↔ REM-phase

Generally, nature shows no redundancy. But it can be applied in technical systems.
- Combine the aforementioned parts
- 2 redundant system models in shift work
- Observer estimates/calculate potential benefits
- Learning algorithm connected to observing entity
- CVS is central system library and knowledge base
Property 1: Performance Maximization...

- ... by intrinsic flexibility
- React on changes and specialize
- Adaptability by using a learning algorithm
- Fitness increase is the benefit
- But the more specialized the less flexible
Property 1: Survivability/Availability...

- ...by intrinsic robustness
- withstand and endure changes
- Fall-back capability of CVS-Lib allows generalization
- Lowering the risks of uncertainty
- Maybe fitness decreases
Ingredients & Modifications

- Network-on-Chip object system
- SystemC model of FPGA
- Kernel-Mechanisms for IP-core management
- FPGA & NoC device drivers

Results

- OS support for runtime reconfigurable systems
- Swapping of IP-cores ⇒ hardware scheduled like virtual memory
- Multiple system models in OS user space
"Grand Challenge"

- Reach missions objectives without human intervention
- Self governance
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Outer Space Missions

- Reach missions objectives in unknown environs
- Improve/not downgrade within functional scope
- Self management
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Telecommunication
- Dynamic environment
- Adapt to, e.g., bandwidth demands
Focus on flexibility and robustness in dynamic environs
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Conceptual framework for adaptive systems
Summary

- Focus on flexibility and robustness in dynamic environs
- Conceptual framework for adaptive systems
- CVS-library is the central entity in the framework
Focus on flexibility and robustness in dynamic environs

Conceptual framework for adaptive systems

CVS-library is the central entity in the framework

⇒ Combining techniques for specialization and generalization
Thank you! Any questions?