Design Space Exploration: Bridging the Gap Between High-Level Models and Virtual Prototype

CRIAQ AVIO509 project
Architectural Exploration for highly integrated and modular avionic systems

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Outline

- Introduction
- Problem
- Solution
- Related Work
- Proposed Methodology
  1- Application specification
  2- AADL High level modeling
  3- ATL transformation
  4- Virtual prototyping
  5- Architecture refinement
  6- AADL model generation

- Experimental results
- Conclusions
- Future work
Embedded System Design

✓ Complexity
✓ Challenges

[Hermann 2008¹]

Performance
Reliability
Robustness
Safety
Cost
Time to market

Model-Based Engineering (MBE)

MBE applied to IMA-based avionic systems

- Previous work done as part of AVIO509 project\(^1\)
- Design flow: AADL \(\rightarrow\) Ocarina \(\rightarrow\) SIMA

**Case Study:** Multi-purpose Control and Display Unit (MCDU) communicating with an external Flight Management System (FMS)

- Covers only the software elements mapped to a simulated ARINC 653 partitioned system

✓ What about the performances on the hardware execution platform?

How to characterize our AADL model on a hardware platform?

**High-Level Analysis:**
- Functionality
- Architecture
- Requirements

**Low-Level Execution:**
- HW components
- Utilization

**Problem**

**Validation**

**Link?**
High-level model  Execution platform

Proposed solution base on:

- Model transformation
- Virtual prototyping
- Design Space Exploration
- Validation
Simulation and performance analysis of AADL models

- **AADL Synthesis (Yue, 2011)**
  - Modeling with Polychrony framework
  - Formal description / verification
  - Simulation model generation

- **Runtime Analysis of AADL models (Chkouri, 2009)**
  - AADL to BIP generation
  - BIP model-checking verification
  - Executable model code generation
  - Simulation-based runtime analysis

- **AADS Simulation Tool for AADL (Gomez, 2012)**
  - AADL model performance analysis
  - System level simulation
  - Verify initial timing constraint
  - SW centric partitioning process
  - Very good review of AADL simulation approaches

And much more in the literature ...
Introduction
Problem
Solution

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Experimental results
Conclusions
Future work
Proposed Design Flow

1. Application Specification
2. AADL high-level modeling
   - AADL Library
   - SystemC behaviour source code
   - Architecture Modeling
   - AADL model
3. ATL Transformation
4. Design Space Exploration
5. Architecture Refinement
6. AADL model generation

Virtual prototyping
- SpaceStudio Library
- SystemC model

SystemC behavior source code
1- Application Specification

- Functional description
- Text document
- Chronogram
- Block diagram

Case study: MJPEG Application
2- AADL High-Level Modeling

- Architecture Analysis & Design Language
- Software system architecture
- AADL component library
- Thread, process, communication interface
- Behavior in SystemC

MJPEG decoder corresponding AADL block diagram
Proposed Design Flow

1. Application Specification
   - AADL Library
   - SystemC behaviour source code

2. Architecture Modeling
   - AADL high-level modeling

3. ATL Transformation
   - AADL model

4. Design Space Exploration
   - SystemC model

5. Architecture Refinement
   - AADL model generation

6. Virtual prototyping
   - SpaceStudio Library
3- ATL Transformation

- Open People Project\(^1\)
- Based on the ATLAS Transformation Language
- AADL to SystemC

- The transformation does not include communication interfaces

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\(^1\)P. Bomel, D. Blouin, "Functional Validation of AADL Models via model Transformation to SystemC with ATL", 5\(^{th}\) international workshop on Model Based Architecting and construction of embedded system, Austria 2012.
Proposed Design Flow

1. Application Specification

2. Architecture Modeling

3. ATL Transformation

4. Design Space Exploration

5. Architecture Refinement

6. AADL model generation

Virtual prototyping

SystemC model
4- Design Space Exploration

- ESL framework: Space studio tool suite
  1- Virtual platform configuration
  2- HW/SW mapping process
  3- Component inter-connection

Space Studio virtual platform configuration manager
4- Design Space Exploration

- Mapping process
- Component inter-connetion

Space Studio binding table used for mapping the application on the virtual hardware platform
5- Architecture Refinement

- Launch execution
- Collect simulation results
- Performance evaluation
- Refinement:
  - Hardware platform parameter
  - Mapping
  - High-level model
6- AADL Model Generation

• From the solution provided by SpaceStudio, one may extract the resulting AADL model enriched with
  ▪ actual bindings of functions to soft-core or IP block
  ▪ refined value for performance metrics

• AADL model to serve as inputs for other analysis
  • Safety, reliability, cost, security, ...

• Part of future work activity
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Virtual Prototype

Space Studio graphical interface representing the Virtual Prototype

Jean-François Boland, ÉTS University, Montréal
Experimental Results (2/4)

CPU workload

Usage of armCortexA91

- VLD1: 27.96%
- IQZZ1: 16.36%
- IDCT1: 19.14%
- DEMUX1: 0.00%
- Context Switch: 32.14%
- IRQ1: 2.93%
- Idle: 1.48%

Jean-François Boland, ÉTS University, Montréal
Possible Mapping Solutions

✓ Starting with a SW centric approach (1)

<table>
<thead>
<tr>
<th>Architecture candidate</th>
<th>Mapping on software</th>
<th>Mapping on hardware</th>
</tr>
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<tbody>
<tr>
<td>1</td>
<td>All tasks</td>
<td>-</td>
</tr>
<tr>
<td>2</td>
<td>DEMUX1, IQZZ1, LIBU1, IDCT1</td>
<td>VLD1</td>
</tr>
<tr>
<td>3</td>
<td>DEMUX1, LIBU1, IQZZ1</td>
<td>VLD1, IDCT1</td>
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<tr>
<td>4</td>
<td>DEMUX1, LIBU1</td>
<td>VLD1, IDCT1, IQZZ1</td>
</tr>
<tr>
<td>5</td>
<td>DEMUX1</td>
<td>LIBU1, VLD1, IDCT1, IQZZ1</td>
</tr>
</tbody>
</table>

➤ Architectural exploration via a task retargeting process
Gain in Processing Speed

Gain in processing speed for the MJPEG obtained using different mappings

Jean-François Boland, ÉTS University, Montréal
Modeling framework to map an AADL model onto a virtual prototype

• AADL high-level modeling

• Automatic SystemC generation from AADL using ATL

• Executable model on a customizable virtual platform using Space Studio

• HW/SW partitioning exploration
1- Include the communication interface in the transformation chain.

2- Perform non-functional analysis using a AADL model generated from Space Studio.

3- Use an avionics application as the case study to test and validate the design flow.
References


THANK YOU!

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