Current Projects at the MIST Laboratory

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Polytechnique Montréal

POLYTECHNIQUE MONTRÉAL

WORLD-CLASS ENGINEERING

Table of contents

Outline

Objectives

- Introduce the lab director
- Introduce the lab and its activities
- Present current and prospective projects
- Identify collaboration and funding venues

Giovanni Beltrame: a short bio

Education

- MS, Electrical Engineering, UIC, USA (2001)
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UIC
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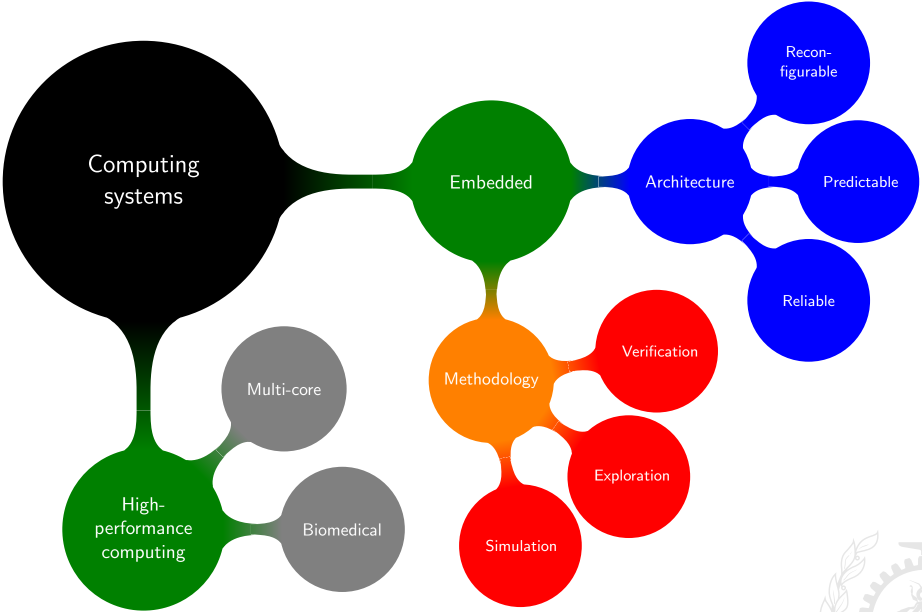
Our research in a nutshell



The MIST Lab - mistlab.ca

- Dedicated to embedded systems for aerospace

Activities and tools

- Modeling and simulation: RESP (resp-sim.googlecode.com) and TRAP (trap-gen.googlecode.com)
- Thermal analysis (ICTherm - ictherm.com)
- Radiation tolerance (InFault - mistlab.ca)
- Optimization (MOMDP - mistlab.ca)

- 2 postdocs (soon), 6 PhD students, 1 MSc student, 2-3 interns
- Lab funded by NSERC, FQRNT and CAE

Outline

Predictable Computing: Rationale

High Performance Data Systems

- Multi- and many-core trend
- Unpredictable timing behaviour
  - Complex architecture, memory hierarchy, shared resources...
  - Being conservative doesn't cut it

Novel approaches

- Deterministic architectures
- Probabilistic architectures
- Self-adaptive systems

Deterministic architectures

- Base Idea: modify computer architecture to guarantee determinism

The MERASA Approach

- Multi-Core Execution of Hard Real-Time Applications Supporting Reliability
- Specialized pipeline, bus, cache, and memory controller

The PTIDES Approach

- Programming Temporally Integrated Distributed Embedded Systems
- Code generation + special OS

Mixed-criticality workloads

- One system shares real-time and non real-time tasks
- Same principle as partitioning
- Non real-time tasks should not affect real-time ones
- Reserved computation and communication resources for real-time tasks

Advantages

- Better use of resources
- Quality of service for real-time tasks

Deterministic components

Deterministic pipelines

- Duplicated resources (i.e. two pipelines)
- One pipeline is reserved for real-time tasks

Deterministic bus

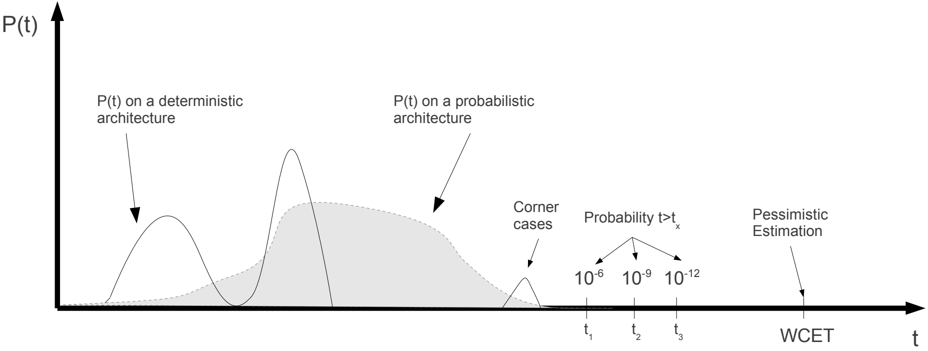
- Time-triggered architecture
- Reserved slots for real-time tasks

Deterministic memory hierarchy

- Cache way isolation and freezing for real-time tasks
- Memory controller prioritizing real-time tasks

Predictable Computing: Probabilistic Architectures

- Allow random behaviour in pipelines and memory hierarchies
- Probabilistic analysis to predit real-time system behaviour



Avantages and challenges

Avantages

- Qualification and integration cost reduction
- Software composability
  - The Integrated Modular Avionics concept remains applicatble
- Approach started with the PROARTIS project (Airbus, ESA...)

Challenges

- Completely random architectures
- Definition of the mathematical tools to calculate probabilities

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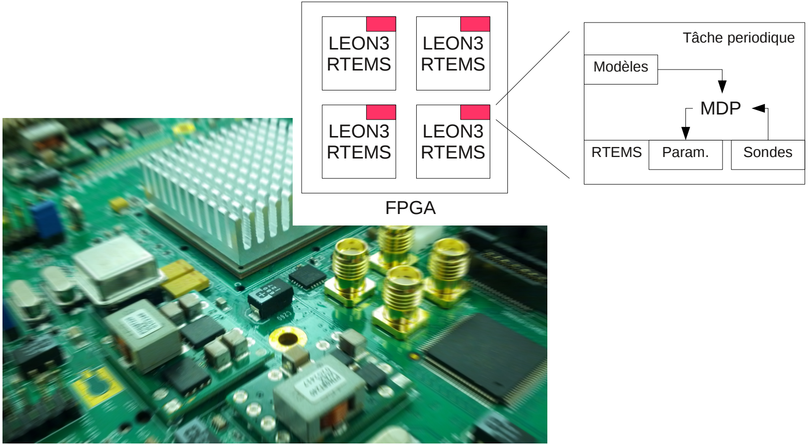
Methodology

- Modified LEON3/GRLib components
- Probabilistically analysable cache: parametric random placement
  - Address rotation + random (re)placement
  - Avoid using expensive fully associative caches
- Thermal noise random number generation
  - Already used in cryptography
- Modelling and simulation using the lab tools
- Prototyping on FPGA

Raising the Technology Readiness Level

- Small satellite mission with the prototye planned

Self-Optimizing Systems



Fonds de recherche Nature et technologies Québec

RESMIQ Regroupement Stratégique en Microsystèmes du Québec

esa

Two Motivating Examples

Complex heterogeneous distributed systems

- How to control the complexity of administration?
- How to manage global goals with variable demand?

Critical Systems

- How to guarantee soft degradation?
- What about unplanned contingencies?

Open Issues in Many-Cores Systems

Challenges

New challenges for designers and developers:

- Thermal management
- Parallelism exploitation
- Resource sharing conflicts
- Reliability and soft degradation
- ...

Interacting and not mutually exclusive!

Machine learning and AI provide tools to manage complexity

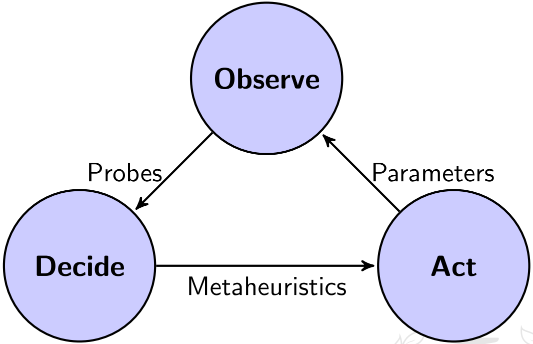
Self-Adaptive Systems

Definition

A self-adaptive computer is capable of adapting its behavior and resources to automatically accomplish a given goal, in changing environmental conditions

Challenges for many-core systems

- Probes & parameters
- Fast algorithms
- Learn complex behaviour



Experimental Setup

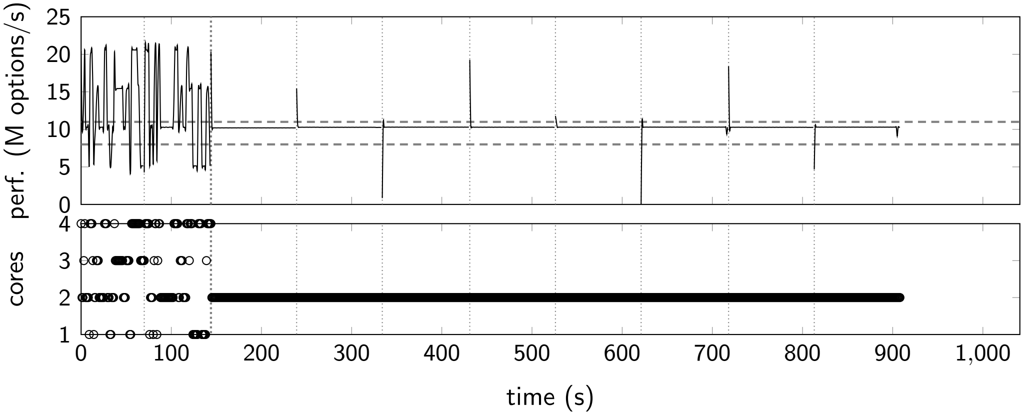
Experimental Goal

- Show that learning can efficiently allocate resources
  - number of cores, frequency step...
- Such that applications deliver user-defined performance goals

Experimental Platform

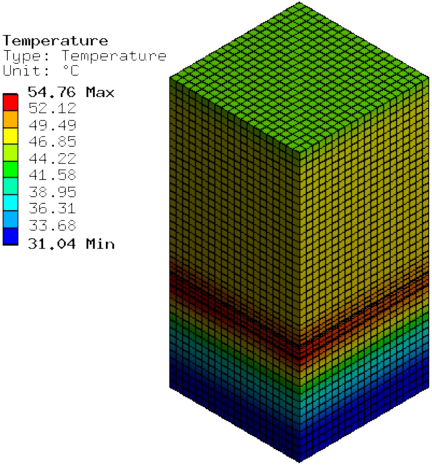
- Adaptation manager implemented in Linux (Intel i7 quad-core)
- Heart-rate monitors for the PARSEC benchmark suite as probes
- Core selection and frequency allocation as parameters
- Two learning algorithms:
  - Q-Learning and Adaptive Dynamic Programming

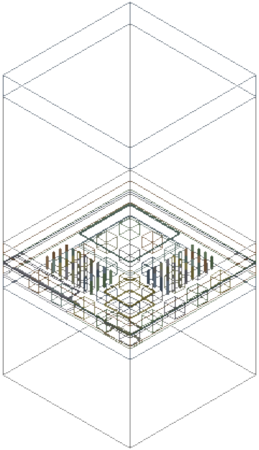
Some Results: Throughput

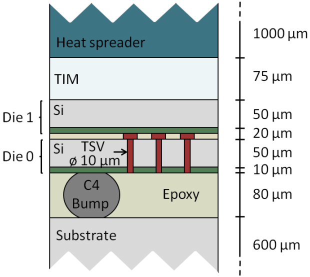


blackscholes PARSEC managed by core allocation

Thermal Modelling of Electronic Devices







RESMIQ
Regroupement Stratégique
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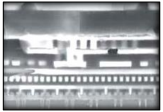
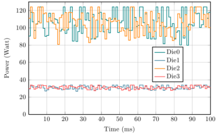
Thermal Modelling of Electronic Devices

Chip structure



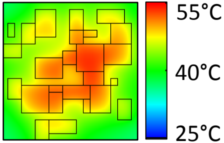
Power dissipation



- Time varying

Thermal simulation

Temperature



Fast and accurate simulation needed

Transient response

Thermal Modelling of Electronic Devices

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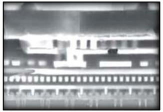

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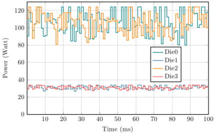

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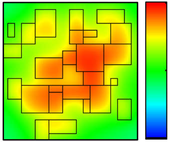

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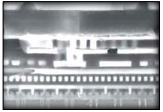

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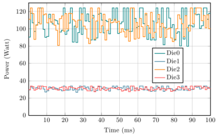

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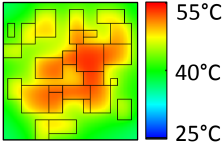

Fast and accurate simulation needed

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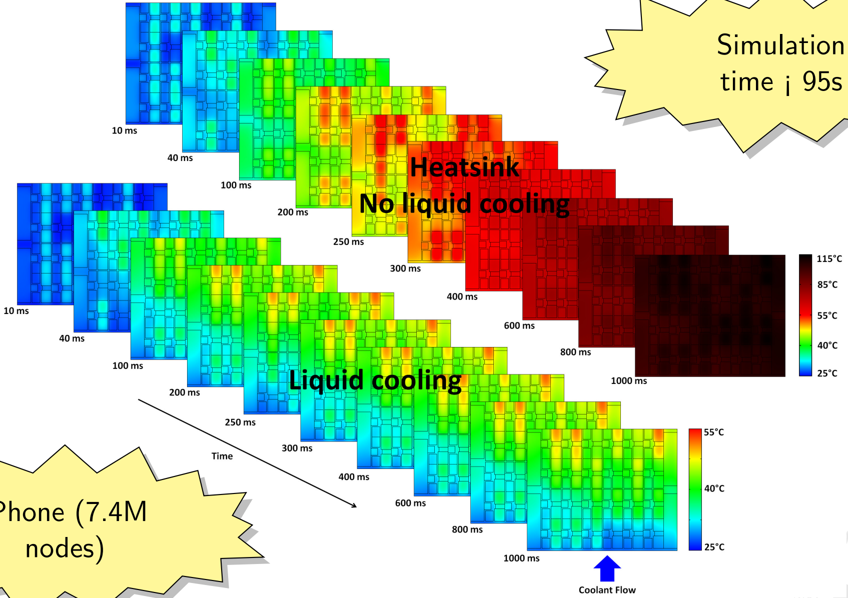
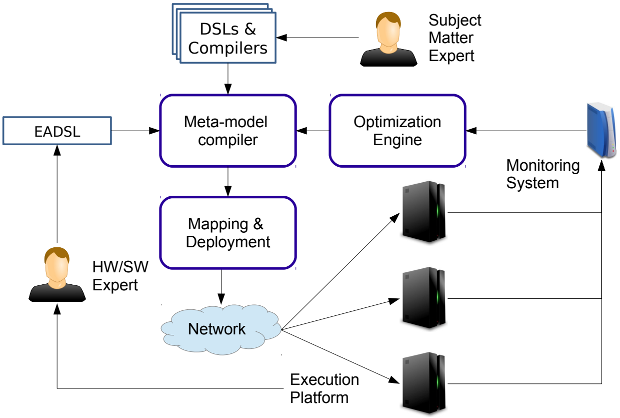
Results:



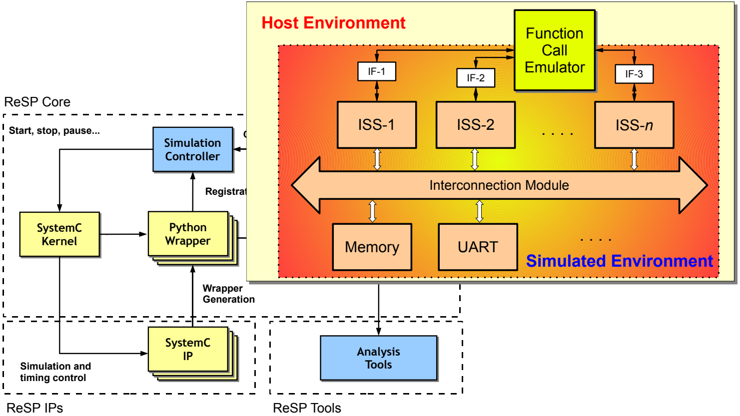
Simulation time ¡ 95s

iPhone (7.4M nodes)

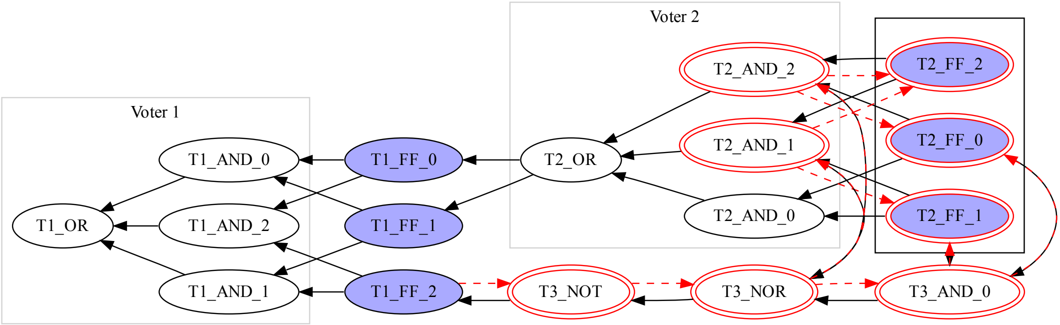
Hardware-aware Real-Time Code Generation



System-level Cosimulation



Verification of Memory Protection Constructs



Additional Projects

- Smart scrubbing of FPGAs for Improved Reliability
- Real-time task mapping
- Device lifetime optimization via slack allocation

Outline

Working together

- Provides access to the lab infrastructure and know-how
- Most background IP is open-source
- Support PhD and MSc students and benefit from their research
- Can be used to discover new talent for the company

Funding Opportunities 1/2

Establishing a collaboration: NSERC Engage Grants

- NSERC pays $25K for a 6-month project
- IP belongs to the industrial partner
- No cash commitment needed, ~ 100% success rate, no deadline
- Ideal to "test" a potential partner

NSERC Collaborative Grants

- NSERC adds x2 the cash amount provided by industry
- IP agreement between university and industrial partner
- 1 to 3-year project, ~ 90% success rate, no deadline
- 3 months turnaround (unless requesting more than $200K/year)

Funding Opportunities 2/2

NSERC Strategic Grants

- \$150K/year completely funded by NSERC, 3-year projects
- IP agreement and in-kind (no cash) commitment needed
- New tech with applications in the following 10 years, $\sim$ 25% success rate
- One call per year, deadline April 1st

CRIAQ Projects

- Combination of provincial and federal funding
- Up to a factor 5x of cash commitment
- Mandatory participation of two companies and two universities
- Standard CRIAQ IP agreement
- No deadline, ideal for more complex projects

Outline

Wrap-Up

- Computer Architecture for many-core real-time systems
  - Deterministic and probabilistic approaches
- Self-adaptive and self healing systems
- Software analysis
- Radiation and fault tolerance

Several opportunities for funded collaboration

- NSERC Engage to kickstart
- More venues for follow-up projects

The End

Questions?

http://mistlab.ca