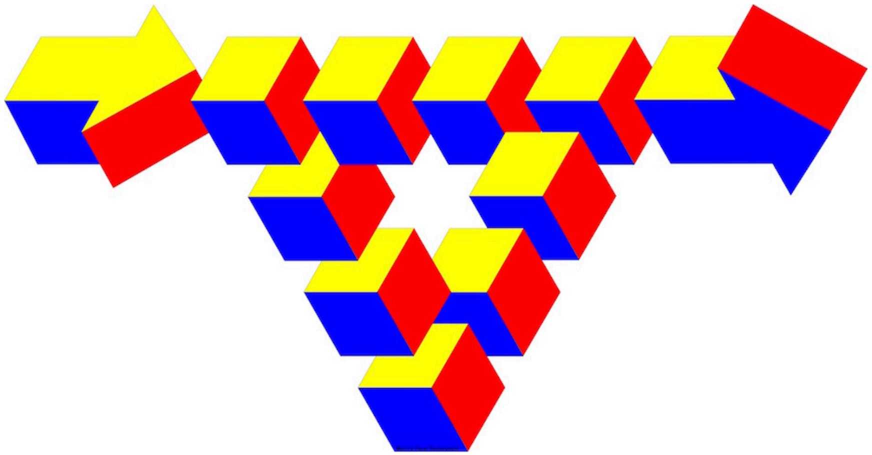


Control for Self-Adaptive, Autonomic Computing

Eric RUTTEN

Ctrl-A people

team @ LIG

permanent

- **Eric Rutten, CR Inria HdR**
- **Gwenaël Delaval, MCF UGA**
- **Stéphane Mocanu, MCF INPG**

external collaborator

- Bogdan Robu (Gipsa-lab)

non-permanent

- **Neil Ayeb (PhD Orange labs)**
- **Adja Sylla (PhD CEA)**
- **Soguy Gueye (post-doc ANR)**
- Chabha Hireche (PhD ANR; Brest)

past non-permanent members

- Soguy Gueye (post-doc, ANR)
- Naweiluo Zhou (PhD Labex)
- Frederico Alvares (post-doc Inria)
- Julio Cano (post-doc Inria)
- Mengxuan Zhao (Cifre, PhD)
- Xin An (PhD, ANR)

Ctrl-A : Control for Autonomic Computing

Automated self-adaptation, reconfiguration & regulation

reaction to variations load, resources,…

large (Cloud, HPC) or **embedded** (IoT)

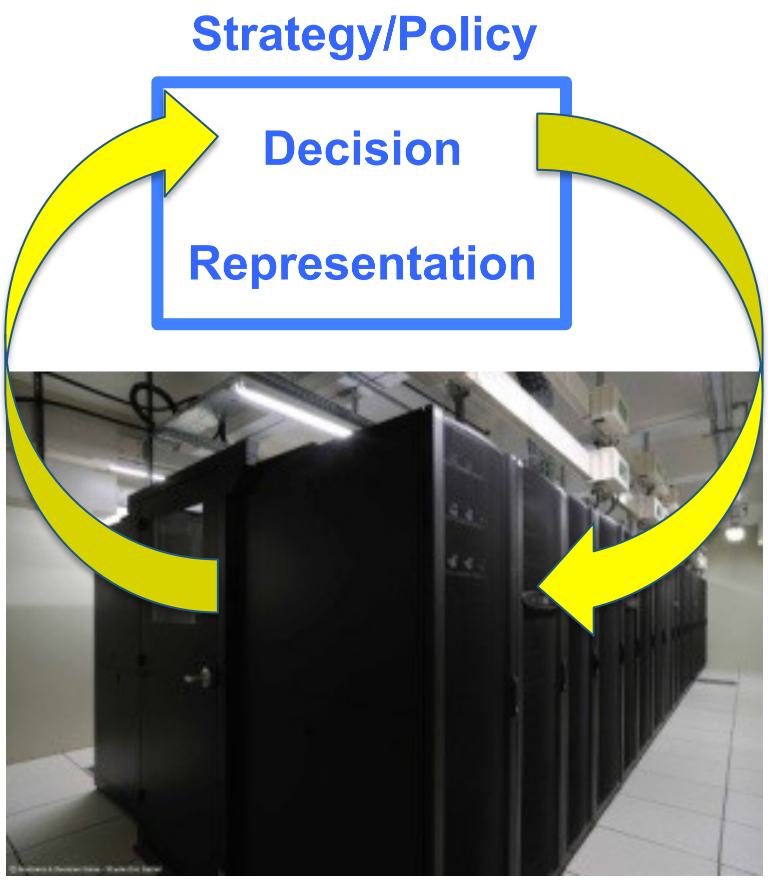
self-*: deploy, mgmt, healing, protection

promising, but **challenge in new development method** : need for **safe automation** & **separation of concerns**

Understand and design control for

efficiency (e.g; energy)

& **assurances** (e.g.crash avoidance)



Eolas, Grenoble

Motivation

- **Our goal:** design **languages** & **model-based methods** **validated** in target domains
- **Method** : attack lack of models & wide range of problems propose **validated generic models**

- **Our approach:** Software Engineering :
  - **Middleware-level** instrumentation and architectures,
  - **Model-based control** (e.g., **Discrete Event Systems**),
  - **Programming support** (**reactive, components**)
- **Targets : HPC, IoT**, mid-size grain, heterogeneous **problems** : navigation in configurations space

- **Multidisciplinarity** : Autonomic Computing, languages + control theory, target platforms (HW/MW/SW)

Autonomic Computing : Example

HPC on **Dynamically Partially Reconfigurable** FPGA

*Controlling choices in **combinatorial space*** **[ICAC13, ACM TECS16]**

ANR FAmous

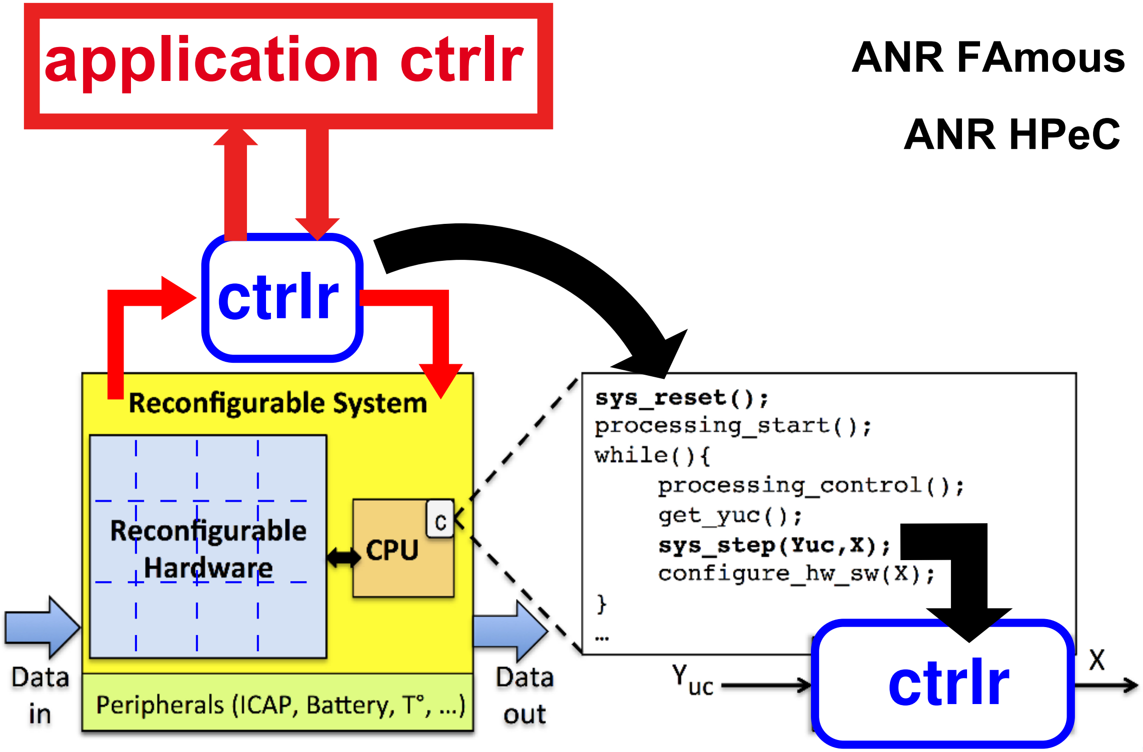
ANR HPeC

Application graph
par., cond. & seq. branches

Tasks versions
Size, WCET, power, QoS

Architecture
sleep modes, DVFS, …

Policies power peak, QoS, surface



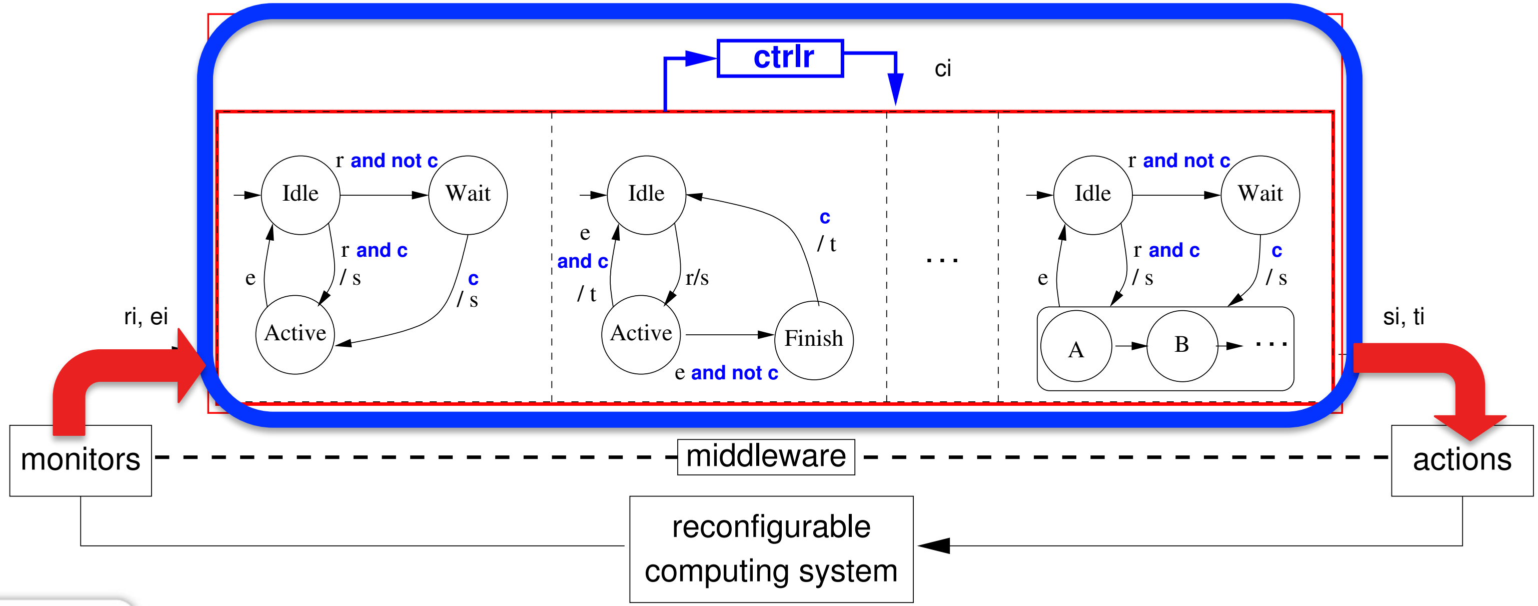
Model-based reconfiguration control

(Re-)Configurations space (focus : **discrete event systems**)

Interfaces Middleware level API : monitored events, actions

Possible behaviors : Automata (parallel, hierarchy) (**Hetagon/BZR**)

Objectives Invariance, reachability, optim. **[SefSas18, IEEE TSE16]**

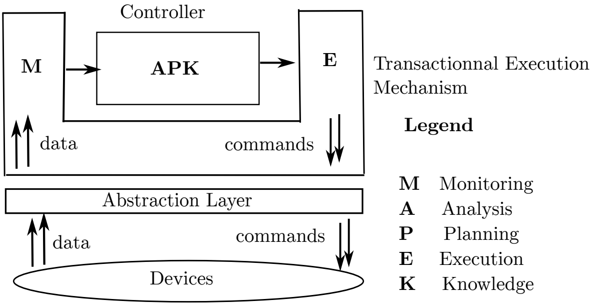


Application to Smart Environments

excerpt from IEEE ICCAC'17 presentation

- **Design Framework for Reliable Multiple Autonomic Loops in Smart Environments**
- **cooperation with CEA Leti PhD thesis of Adja Sylla**
  - **transactional middleware Linc**
  - **applications in Smart office / building**
- **methods :** *Control meets Software Engineering*
  - **design of safe controller** using H/BZR
  - **multiple loops** to be coordinated

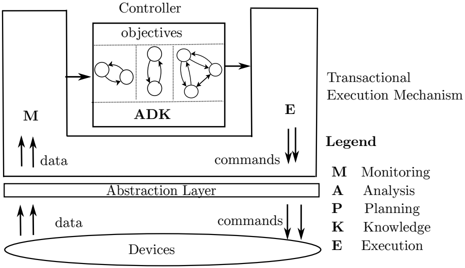
Generic Autonomic Loop



Implementation

- Transactional Middleware (**LINC** [Louvel and Pacull, 2014])
- Reactive language (**Heptagon/BZR** [Delaval et al., 2013])

Single Loop



Two kinds of reliability

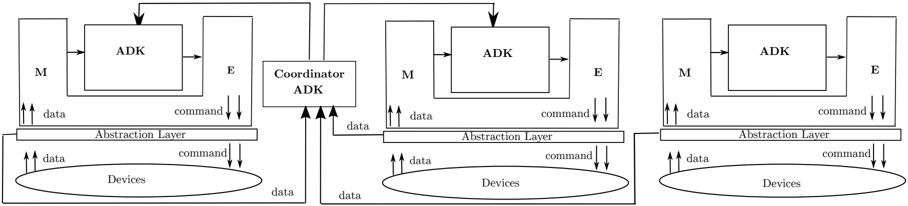
- Behavioral
- Transactional

Other types of controllers

- Hand written
- Based on model checking [Sylla et al., 2015]
- Based on control theory [Vergara-Gallego et al., 2016]

Single Loop: Limited

Coordinated Parallel Loops



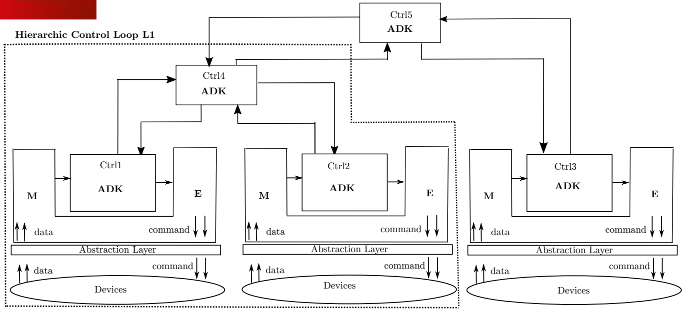
Principle

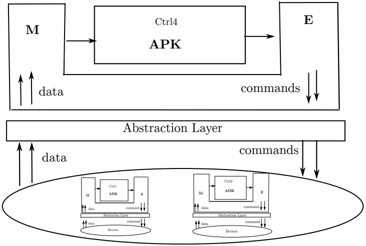
- Inhibit an action of a controller
- Using a coordination variable

Coordinator Design

- Manually: using LINC
- Generation: using Heptagon/BZR

Hierarchic Loops





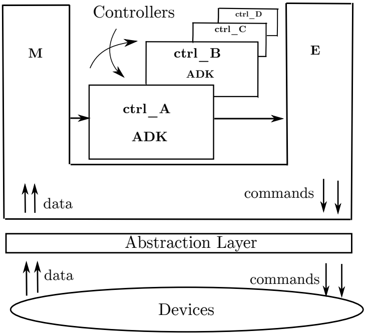
Motivation

- Scalability
- Re-usability
- Structuring

Design

- Manually: in LINC
- Generation: in Heptagon/BZR

Loop Adaptation



Principle

- Controller reconfiguration
- Conditions related to states

Controller Reconfiguration

- In LINC: writing rules
- In Heptagon/BZR: automata and contract

Case Study Description

Office

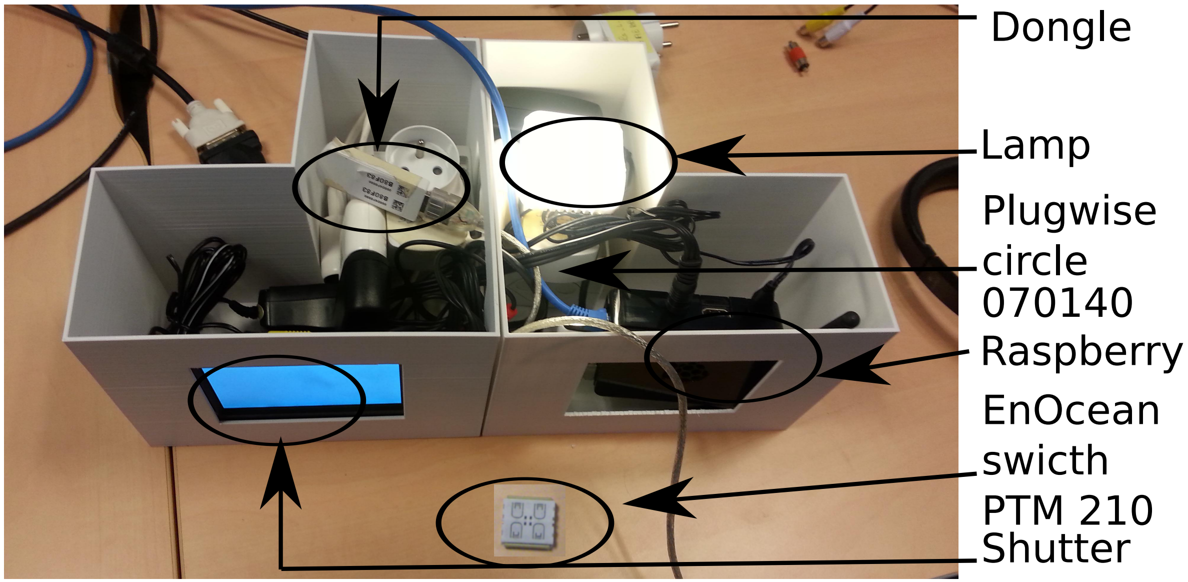
- **Sensors:** temperature, noise, luminosity, CO_2, presence, Agenda
- **Actuators:** window, door, lamp, shutter, MV, RAC

Objectives

- presence $\Rightarrow$ luminosity in [500,600] lux and noise < 80 dB
- presence and temperature > 17 °C (> 27 °C) $\Rightarrow$ heat (resp. cool)
- presence and $CO_2 > 800$ ppm $\Rightarrow$ ventilation
- presence and confidential meeting $\Rightarrow$ office completely closed
- between two meetings $\Rightarrow$ quick ventilation
- not pollution by pollen or outdoor CO_2
- minimize energy consumption

Case study

- **Smart home / office** Two loops with hierarchical controllers
  Lum loop : lamp, shutter
  TempAirNoise: loop: shutter, window, door, MV, RAC
- **Experimental validation on a model**



Conclusion

- **Goals**

  tools–supported methods for autonomic controllers design

  validated by applications in large & small systems

- **Applications**

  HPC / Cloud infrastructures, FPGA reconfigurable architectures

  e.g. jLESC joint lab (Inria, Barcelona, ANL, RIKEN @Kobe, …)

  IoT, smart environments (home, office, building)

- **Perspectives**

  adaptive control : adaption of the controller itself

  heterogeneous architectures : e.g. FPGA in data-centers, or comm. networks

  self-protection : levels of risk/protection, cost w.r.t. functionality

Recent results : Papers Journals JSS, IEEE TSE, jFACS, ACM TECS, ACM TODAES, FGCS **Book chap.** SefSas3 (LNCS) **Confs.** CCTA17; ICAC16,15; ECSA15; COORDINATION17,14,13; CBSE 14,10 (best paper) **Advising** 4 PhDs, 3 post-d. **Software** Heptagon/BZR, Ctrl-F **Projects** 4 ANR; 3 Labex ; Orange, CEA; JLESC