AGILE

rApidly-deployable, self-tuninG, self-reconfIgurabLE, nearly-optimal control design for large-scale nonlinear systems

FP7-ICT-2009.3.5: ICT for Networked Embedded & Control Systems
C. Control of Large-Scale Systems

http://www.agile-fp7.eu

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AGILE Objectives

- Scalable and Nearly-Optimal Control for general Large-Scale Nonlinear Systems (with emphasis on systems with intense computational requirements)
- Rapid Self-tuning, Fault-Recovery, Re-configuration for general Large-Scale Nonlinear Systems
- Interfaces for Embedding the above tools to open-architecture SCADA/DCS in an "easy-to-understand" and "easy-to-operate" manner
- Implementation and Evaluation in two Large-Scale Test Cases:
  - EPB (FIBP Building, Kassel, Germany)
  - Urban Traffic Control (Chania, Greece, the whole city's network)

AGILE Key Issue 1
Dealing with Nonlinear Large-Scale Systems

Given

- the nominal model of the large-scale system dynamics,
- the system requirements and constraints,
- possible faults and incidents and future predictions of the exogenous factors;

Provide a scalable control design that proactively schedules the Large-Scale Control System (LSCS) actions so that its performance is – as close as desired to – the optimal LSCS.

Assumption: Perfect knowledge of system and exogenous factors

AGILE Key Issue 1

Adopted Approach

- The **Convex Control Design (ConvCD)** methodology
- The problem:

Minimize (AGILE – OPTIMAL) ^{2}

subject to

AGILE is EFFICIENT (stable and beyond)

- Is transformed into a convex optimization problem (Least-Squares s.t. SemiDefinite Programming constraints)

AGILE Key Issue 1

Main Achievement so far

- Render ConvCD into a fully operational tool (software module) that provides:
  - Efficient and arbitrarily close to optimal controller (i.e., solves efficiently the ConvCD optimization problem)
  - Scalable controller: PieceWise Linear (PWL) or PieceWise NonLinear (PWNL) controller
  - Extension to the case where not all of the states are measurable (output feedback control) and the case of exogenous factors (predictive control)
  - Off-line performance estimates and estimates of close-to-optimality (in a similar way as standard linear control)
- Successfully tested in various small- and medium-scale systems

AGILE Key Issue 2
Adapting to uncertainties & changes

Assuming that Key Issue 1 has been successfully addressed, to provide with a computationally efficient methodology that:

- quickly detects and identifies variations and changes in the nominal system dynamics and exogenous factors as well as
- faults and atypical system behavior and
- rapidly, safely and efficiently re-designs (or even re-configures) the LSCS to effectively achieve its mission.

AGILE Key Issue 2

Adopted Approach (original)

- Combine an Adaptive Fine-Tuning scheme (successfully implemented for the automated fine-tuning of a large variety of applications)
- with Multi Mode Adaptive Control with Mixing (MMACM)
- in a *hybrid fashion*

AGILE Key Issue 2

Main Achievement so far

- Work for this Key Issue to be completed in Y2.
- Theoretical as well as simulation experiments established the validity of the proposed approach.
- <u>However</u>: A new approach was developed that is significantly superior than the original
- As a matter of fact, the adaptive control design problem can be formulated as a ConvCD problem!
- <u>AdConvCD: adaptive convCD</u>

AGILE Key Issue 3
Embed «easily» in exsiting LSCS

Operator interfaces (go "beyond SCADA")

- Develop (software interfacing) tools for existing open-architecture SCADA/DCS that
  - will allow the operator to easily incorporate a large variety of performance objectives, requirements and constraints.

1. *Can you make sure that the work, experience, effort done so far is not «thrown away»?*
2. *Can you incorporate objectives, requirements and constraints not possible before?*
3. *Can you allow the operator to «tune» the control system in an «easy-to-understand»way?*

AGILE Key Issue 3

Approach:

- “Translate” objectives, requirements and constraints as understood by operators (e.g. “if-then-else” rules)
- into constraints that are in a suitable form embeddable in the optimal control framework of ConvCD (nonlinear constraints).

AGILE Key Issue 3

Main Achievement so far

- Identifaction of the requirements, objectives and constraints in a variety of large-scale control applications
- Development of a methodology for translating operator-imposed requirements, objectives and constraints into ConvCD-compatible Constraints
- Development of tools for interfacing the AGILE system with existing SCADA/DCS

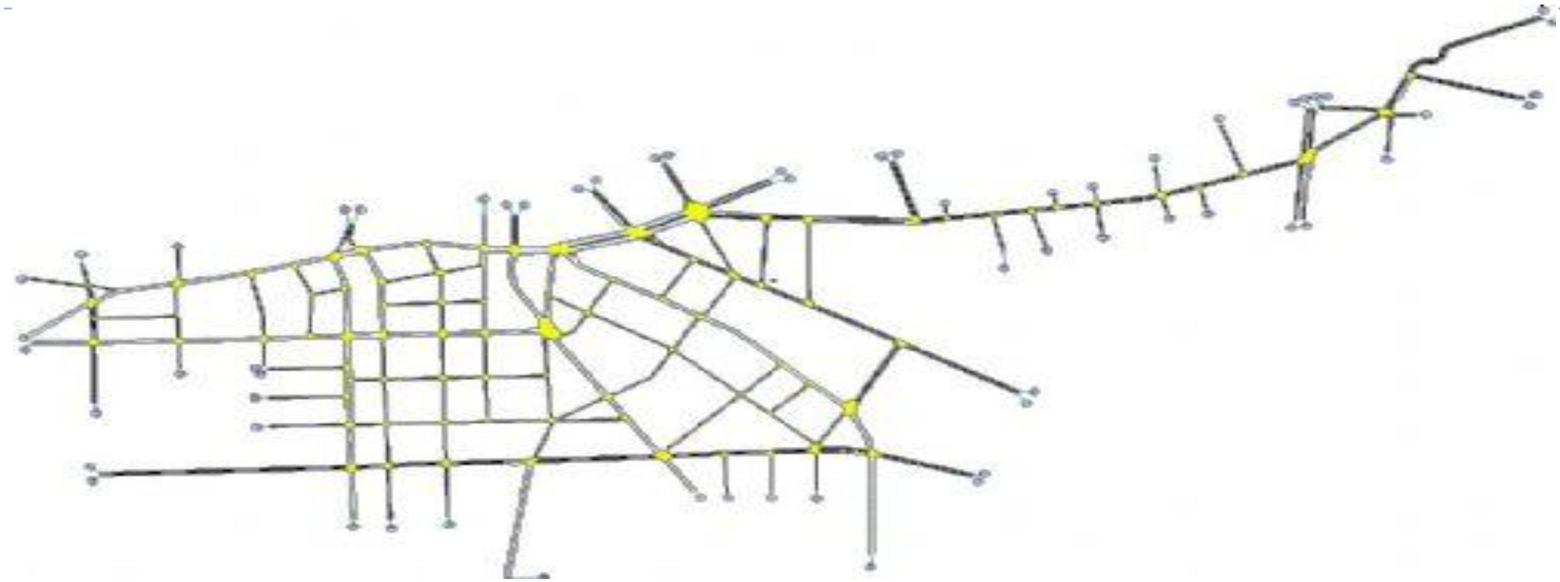
The AGILE Test Cases

- Test Case 1: The Traffic Network of Chania, Greece
- Test Case 2: FIBP Building, i.e., (the building we are currently in!

The AGILE Test Cases Challenges

- Highly Nonlinear Dynamics
- Significant System Variations
- Large system dimension:
  - Test Case 1: ~80 states, 43 control inputs
  - Test Case 2: >700 states, ~170 control inputs
- Absense of a state-space models (but quite elaborate simulation models exist)
- «Hard-to-meet» constraints/rules using existing control design methods:
  - Test Case 1: Summation of green times=Cycle Time – Lost times
  - Test Case 2: if-then-else constraints (e.g., if it rains then close windows)
  - Test Cases 1 & 2: **if-then-else rules that work very well and it is not «straightforward» for the control design to «invent»** (e.g., if it is sunny and the temperature less than xx and … then open blinds)

The AGILE Test Cases
2. Urban Traffic control



Location:
Chania, Greece

Characteristics:

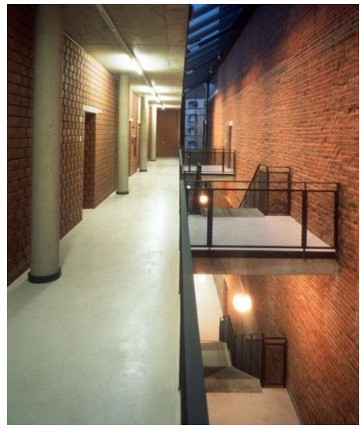
20 Junctions

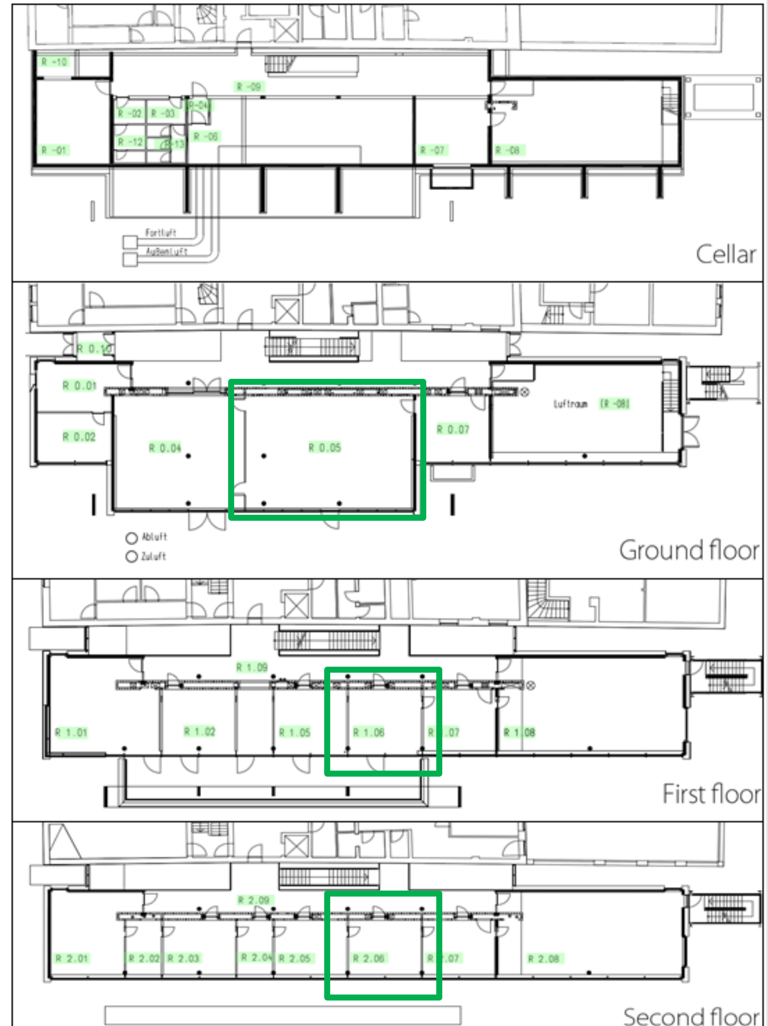
Complex Junction Geometry

Congestion

Frequent Sensor Failures and Incidents

The AGILE Test Case Building (Kassel, Germany)





AGILE Partners

	AGILE Participants
1	Center for Research and Technology – Hellas (CERTH)
2	University of Cyprus (UCY)
3	The Pennsylvania State University – Penn State (PSU)
4	Afcon Software and Electronics Ltd. (AFCON)
5	Sociedad Iberica de Construcciones Electricas SE (SICE)
6	Siemens AE Electrotechnical Projects and Products (SIE)
7	Fraunhofer Institute for Building Physics (FIBP)
8	Traffic Control Department – City of Chania (TCD)

•Coordinator: CERTH

•CERTH & UCY lead the ConvC and AdConvCD developmetnts

•PSU (from USA will help on optimization & implementations)

•AFCON & SICE lead the interfaces' developments

•Test Case 1: SIE & TCD

•Test Case 2: FIBP

•Evaluation: FIBP

•D&E: AFCON

SEVENTH FRAMEWORK PROGRAMME