NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Decision and Control Techniques for Energy Management of Smart Cities

Ph.D. candidate

Alaa Ali Hameed HAMEED

Cycle

XXXVIII

Tutors

Prof. Engr. Mariagrazia Dotoli

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1. Description of the research program

A smart city is a sustainable and efficient urban centre that provides a high quality of life to its inhabitants through optimal management of its resources. Energy management is one of the most demanding issues within such urban centres owing to the complexity of the energy systems and their vital role. As a consequence, to increase smartness, cities should improve present systems and implement new solutions in a coordinated way and through an optimal approach, by profiting from the synergies among all the involved urban actors. Against this background, this project will develop decision and control tools that address the emerging need of intelligent energy management systems for smart cities and related subsystems such has energy clusters, districts, communities, smart buildings, and smart homes. On the one hand, optimization tools devoted to the strategic management of urban energy systems will be investigated to make urban infrastructure and facilities more energy efficient and environmentally friendly in a cost effective manner. On the other hand, this project will define decision and control techniques for the operational management of urban smart energy systems, with the final aim of ensuring the transition towards a low-carbon energy sector and the efficient and sustainable use of natural resources from users' perspective. The research will be applied to real urban case studies in collaboration with the Smart Cities and Communities Laboratory of the Italian National Agency for New Technologies, Energy and Sustainable Economic Development (ENEA).

Making normal homes/buildings/districts/communities into smart homes/buildings/districts/communities that use information and communication technologies to improve energy efficiency is one of the intended solutions to these problems. These technologies will also produce enormous volumes of data regarding their operating environments, operational status, infrastructures, and inhabitants, which can be effectively exploited to enhance the decision and control techniques for the energy management of smart cities and related subsystems. As a consequence, this research project will investigate the integration of control and decision-making techniques with data-driven methods such as deep learning and machine learning algorithms.

In particular, the project will focus on:

- Data driven control, and particularly data-driven MPC
- Deep learning combined to game-theoretical control.

2. Schedule of the research activities

First academic year (planned)

	Description	**Period**	**Activity abroad**
Systematic literature review	Study of data driven control approaches as applied to energy management of smart cities.	months 1-3	No
Systematic literature review	Study of deep learning and game-theoretical control techniques as applied to the energy management of smart cities.	months 4-6	No
Compilation of a literature review and bibliography on the research topics	Study of the existing control systems in the energy management of smart cities.	months 7-12	No
Research work	Individual research activity and preparation of manuscripts.	months 4-12	No

Second academic year (planned)

	Description	Period	Activity abroad
Definition of novel control techniques	Definition of new data-driven control architectures and framework for the energy management of smart cities.	months 1-6	No
Experimentation	Simulation and testing of the defined decision and control policies using realistic scenarios of smart cities. Activities to be conducted at ENEA - Smart Cities and Communities Laboratory, Rome (Italy).	Months 7-12	No
Research work	Individual research activity and preparation of manuscripts.	Months 1-12	No

Third academic year (planned)

	Description	Period	Activity abroad
Definition of novel control techniques	Definition of new control architectures and framework based on deep learning and game-theory for the energy management of smart cities. Preparation of manuscripts. Activities to be conducted at the Automatic Control Department, Universitat Politècnica de Catalunya, Barcelona (Spain).	months 1-6	Yes
Experimentation	Application of the control techniques to real case studies of smart cities.	months 7-9	No
Research work	Individual research activity and preparation of manuscripts.	months 7-9	No
Preparation for final dissertation	Writing of the PhD dissertation.	months 10-12	No

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Linear and nonlinear Kalman filtering: theory and applications (DAUSY course)	January-February 2023	Yes	1.5
	Introduction to modeling, analysis and control of complex systems (DAUSY course)	January-February or June 2023	Yes	1
	Linear algebra for control applications (DAUSY course)	Spring 2023	Yes	2
	Optimal control for Climate change and air quality (DAUSY course)	March-April 2023	Yes	1

	Duality-based decentralized and distributed optimization (DAUSY course)	June/July 2023	Yes	1
	Model Predictive Control (IMT School for Advanced Studies Lucca, online)	April 2023	Yes	2
	Distributed optimization for cooperative robotics and decision making: theory, numerical methods and toolboxes (International Graduate School on Control - EECI)	June 2023	Yes	3
B. Master's degree courses	Dynamical Systems Theory (Automation Engineering MSc Degree - Poliba)	First semester	Yes	6
C. Soft skill courses				
D. Participation to seminars	Applied data-driven fault diagnosis (DAUSY seminar)	February-March 2023		1.5
	Complex Systems Modeling (DAUSY seminar)	TBD		1.5
	Introduction to dynamic control allocation (DAUSY seminar)	November 2022-March 2023		3
	Sustainable exploitation of renewable energy sources (DAUSY seminar)	TBD		1.5
E. Participation to international congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			25
G. Individual research activity	Individual study and simulations through experimental work at the laboratory.			30
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Research articles writing and submission.			5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			35
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	**Period**	**Final Exam**	**ECTS**
A. Ph.D. courses	PhD course selected among the available ones		Yes	2
	Winter or Summer Schools		No	3
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Seminars			6
E. Participation to international	Participation in an international conference			4

congresses or workshops				
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			15
G. Individual research activity	Individual Research activity			25
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Writing and reviewing of academic articles for journal and / or conference publications			20
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			45
	TOTAL OF ECTS			**60**

Third academic year (planned)

	Description	**Period**	**Final Exam**	**ECTS**
A. Ph.D. courses				
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Seminars			6
E. Participation to international congresses or workshops	Participation in an international conference			4
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			10
G. Individual research activity	Individual Research activity and preparing the final dissertation			30
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Writing and reviewing of academic articles for journal and / or conference publications			20
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			50
	TOTAL OF ECTS			**60**

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