



NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

# **Model-based design for increasing reliability and safety of autonomous systems**

## **Ph.D. candidate**

Shafqat Ali SIYYAL

## **Cycle**

XXXVIII

## **Tutors**

Prof. Sauro Longhi

Prof. Alessandro Freddi

Prof. Francesco Ferracuti

# 1. Description of the research program

Recent years have seen significant progress in developing autonomous systems and their applications, resulting in high-profile successes in both the civilian and military sectors. Aside from these successes, several high-profile failures demonstrate the difficulties associated with natural behavior specifications for truly autonomous systems. However, advancing this technology has substantial rewards. The technology of autonomous systems has the potential to reduce both costs and risks. Moreover, it also holds the potential to enable entirely new capabilities in environments where direct human control is not possible.

There are various engineering systems that are considered safety-critical, such as manufacturing systems, aero engines, chemical processes, vehicle dynamics, wind energy conversion systems, power networks, electric machines, and industrial electronic equipment. It is becoming increasingly important for industrial systems to be reliable and safe, particularly when they are exposed to potential abnormalities and component failures. As a result, detecting and identifying potential abnormalities and faults as early as possible, as well as implementing fault-tolerant operations, is crucial to minimize performance degradation and prevent dangerous situations.

In this scenario, the first part of the research will focus on studying the state of the art of linear and nonlinear techniques for fault detection and diagnosis, as well as fault-tolerant control methods, using both active and passive approaches. In addition, a study will be conducted on the faults and failure modes, such as actuation faults, sensor faults, process faults, and faults at the control level. The second part of this research will focus on the development and design of model-based methodologies. The proposed methodologies may also operate for autonomous systems operating in a distributed manner. The last part of this research will be to apply and validate the proposed methodologies, which may include unmanned vehicles, mobile robots, industrial manipulators, and intelligent machines.

## 2. Schedule of the research activities

Insert the research activities that you plan, or you have completed for the three years, including any period abroad.

### First academic year (planned)

	<b>Description</b>	<b>Period</b>	<b>Activity abroad</b>
<b>Research Planning</b>	The identification of a problem statement and the selection of an application area.	M1-M5	No
<b>Background Study</b>	The study of new methodologies and a detailed review of the literature. Formulating the problem and suggesting solutions in the preliminary stage	M6-M12	No

### Second academic year (planned)

	<b>Description</b>	<b>Period</b>	<b>Activity abroad</b>
<b>Abroad Experience</b>	Definition of the case study in collaboration with the Control Systems Technology team, Department of Mechanical Engineering, Eindhoven University of Technology	M13-M18	Yes
<b>Problem Statement</b>	Designing platforms and architectures for the specific case study, formulating problems and proposing solutions	M18-M21	No
<b>Simulations</b>	Analytical solutions and first validation in simulation with regards to the specific case study.	M22-M24	No

### Third academic year (planned)

	<b>Description</b>	<b>Period</b>	<b>Activity abroad</b>
<b>Compiling the Results</b>	Dissemination of research findings from previous year's activities.	M25-M30	No
<b>Articles Submission</b>	Thesis writing, editing and submission	M31-M36	No

### 3. Training and research activities plan

#### First academic year (planned)

	Description	Period	Final Exam	ECTS
<b>A. Ph.D. courses</b>	Analysis and control of cyber-physical systems, Giordano Pola (L'Aquila)	30 hours	Yes	3
	Linear algebra for control applications, Luca Schenato (Padova)	20 hours	Yes	2
	Linear and nonlinear Kalman filtering: theory and applications, Luigi Chisci (Firenze)	15 hours	Yes	1.5
<b>B. Master's degree courses</b>	Control and identification in bioengineering, Andrea Monteriù (Politecnica Marche)	48 hours	Yes	6
<b>C. Soft skill courses</b>				
<b>D. Participation to seminars</b>	Introduction to fault diagnosis and fault prognosis, Alessandro Freddi (Politecnica Marche)	5 hours	No	1.5
	Applied data-driven fault diagnosis, Francesco Ferracuti (Politecnica Marche)	5 hours	No	1.5
<b>E. Participation to international congresses or workshops</b>	IEEE / IFAC International Conference	3 days	No	3
<b>F. Presentation of research products at international congresses or workshops</b>				
	<b>TOTAL OF ECTS FOR TRAINING ACTIVITIES</b>			<b>18.5</b>
<b>G. Individual research activity</b>				36.5
<b>H. Supervision of students</b>				
<b>I. Integrative teaching activities</b>				
<b>J. Preparation of manuscripts for conferences or journals</b>				5
	<b>TOTAL OF ECTS FOR RESEARCH ACTIVITIES</b>			<b>41.5</b>
	<b>TOTAL OF ECTS</b>			<b>60</b>

#### Second academic year (planned)

	Description	Period	Final Exam	ECTS
<b>A. Ph.D. courses</b>	Summer School SIDRA (Bertinoro)	5 days	Yes	5
	EECI Internation Graduate School – 1 Module	21 hours	Yes	3
<b>B. Master's degree courses</b>	Fault diagnosis and predictive maintenance, Alessandro Freddi (Politecnica Marche)	48 hours	Yes	6
<b>C. Soft skill courses</b>				
<b>D. Participation to seminars</b>	Hacking the control systems, Federica Pascucci (Roma 3)	5 hours	No	1.5
	Network dynamics and control, Mattia Frasca (Catania)	10 hours	No	3

<b>E. Participation to international congresses or workshops</b>	IEEE / IFAC International Conference	3 days		3
<b>F. Presentation of research products at international congresses or workshops</b>				
<b>TOTAL OF ECTS FOR TRAINING ACTIVITIES</b>				<b>21.5</b>
<b>G. Individual research activity</b>				33.5
<b>H. Supervision of students</b>				
<b>I. Integrative teaching activities</b>				
<b>J. Preparation of manuscripts for conferences or journals</b>				5
<b>TOTAL OF ECTS FOR RESEARCH ACTIVITIES</b>				<b>38.5</b>
<b>TOTAL OF ECTS</b>				<b>60</b>

### Third academic year (completed/planned)

	Description	Period	Final Exam	ECTS
<b>A. Ph.D. courses</b>				
<b>B. Master's degree courses</b>				
<b>C. Soft skill courses</b>				
<b>D. Participation to seminars</b>				
<b>E. Participation to international congresses or workshops</b>				
<b>F. Presentation of research products at international congresses or workshops</b>	IEEE / IFAC Internation Conference	3 days		3
<b>TOTAL OF ECTS FOR TRAINING ACTIVITIES</b>				<b>3</b>
<b>G. Individual research activity</b>				52
<b>H. Supervision of students</b>				
<b>I. Integrative teaching activities</b>				
<b>J. Preparation of manuscripts for conferences or journals</b>				5
<b>TOTAL OF ECTS FOR RESEARCH ACTIVITIES</b>				<b>57</b>
<b>TOTAL OF ECTS</b>				<b>60</b>

#### **4. List of the publications written by the candidate in the triennium**

Insert the list of papers written during the Ph.D. program. If the paper is still not published indicate its status (e.g., submitted, under review, under 2nd review round, accepted to appear, etc.).

##### **International Journal Articles**

##### **International Conference Proceedings**

Shafqat Ali Siyyal

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