NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Predictive maintenance, fault and anomaly detection for chemical and pharmaceutical processes

Ph.D. candidate

Daniele ANTONUCCI

Cycle

XXXVIII

Tutors

Dott. Ing. Luca CONSOLINI

Dott. Ing. Gianluigi FERRARI

1. Description of the research program

The proposed research program is made by the collaboration between GSK and UNIPR, focusing on leak detection and predictive maintenance. Predictive maintenance is a focal point in complex system, where various variables affect the state of the whole system. When it comes to predictive maintenance, its usage in one industrial area leads to the analysis and processing of a large amount of data from machinery, which is typically gathered by specialized sensors situated in key areas of the machinery itself.

Starting from this statement and previous implementations that uses only data from a freeze-dryer machine, the first main goal is to obtain data from heterogeneous machines, within the same system, and aggregate them to generate an accurate dataset for Artificial Intelligence (AI) model training. AI techniques are nice tools to generate a statistical model able to describe the nominal operation of the line, starting from the nature of data.

The next part focuses on comparing different models and analyzing results, through an evaluation of improvements made by models and ability to detect anomalies in a preventive way.

The result will be a mathematical model able to describe the system, detect anomalies, through an implementation of predictive maintenance operations.

Schedule of the research activities

The research program's first step is to analyze and study results and state of the art of the relevant literature. The solution, previously developed under an agreement between GSK and UNIPR, will be analyzed and any improvements and changes will be proposed, using current literature on anomaly detection and predictive maintenance. The follow-up step is data collection of a GSK production line, integrating information coming from different systems.

Automatic, data-oriented techniques will be developed and implemented to obtain a mathematical model, describing the nominal operation of the line. Models will be used for detecting anomalies and to highlight degraded situations of components that require maintenance.
The new techniques proposed will be tested and compared to find improvements of the reliability and safety of the production line.

First academic year (planned)

	Description	Period	Activity abroad
Study of previous results	Analysis of state of the art and previous results obtained between GSK and UNIPR.	I semester 2022/2023	NO
Study of relevant literature	Analysis of lyophilization quantitative models found in literature	I and II semester 2022/2023	NO

Second academic year (planned)

	Description	Period	Activity abroad
Data Analysis	Data collection and aggregation for a GSK pharmaceutical production line.	I and II semester 2023/2024	YES
Model design and simulation	Development of a mathematical model for detecting faults and predictive maintenance in a pharmaceutical system.	I and II semester 2023/2024	YES

Third academic year (planned)

	Description	Period	Activity abroad
Design of AI detection techniques	Development of anomaly detection and predictive maintenance techniques.	I and II semester 2024/2025	NO
Performance analysis	Analysis of the results obtained in a real case scenario	I and II semester 2024/2025	NO

2. Training and research activities plan

Ph.D. students are required to carry out activities for an amount of 60 ECTS (CFU) per year, for a total of 180 ECTS throughout the academic course. The activities carried out by Ph.D. students are divided into:

- **Didactic activities:** min 36 – max 60 ECTS (of the total 180 ECTS), preferably in the first two years of the course.
- **Research activities:** min 120 – max 144 ECTS (of the 180 total ECTS)

The ECTS related to the **didactic activity** can be obtained, for instance, by attending courses and seminars from graduate schools or master's degree programs. The DAUSY teaching-course catalogue (http://dausy.poliba.it/Ph.D./teaching-course-catalogue/) comprehends a list of didactic activities that can be included in this plan. Didactive activities are divided into:

A. **Ph.D. courses:** these are courses offered at the Ph.D. level usually by doctoral schools (e.g., DAUSY Courses, Poliba ScuDo Courses, SIDRA Summer School Courses, EECI IGSC Courses, Partner Universities Ph.D. Courses, etc.).
B. **Master's degree courses**: maximum 18 ECTS can be obtained by master's degree courses or single-cycle degree courses if these have not been attended by the Ph.D. student during his/her second level education.
C. **Soft skills:** maximum 12 ECTS can be obtained by courses classified as "soft skills" after the authorization of the Academic Board.
D. **Participation to seminars**: participation to seminars related to the research program is considered as a didactic activity (5 hours of seminar = 1.5 ECTS).
E. **Participation to international congresses or workshops**: participation at international congresses and workshops is considered as a didactic activity (1 international congress/workshop day = 1 ECTS).
F. **Presentation of research products at international congresses or workshops:** presentation of a research product at international congresses and workshops is considered as a didactic activity (1 presentation = 2 ECTS).

Note that:

- **At least 18 ECTS (of the total 180 ECTS) of didactic activities (A) and (B) must be obtained by completing a final exam**.
- For all courses (A) and (B) the 50% of the total course ECTS is recognized in case the final exam is not completed.
- Didactic activities must be confirmed with attendance certificates.

Examples:

- A 6-ECTS course, given in a master's degree course, can be attended by the Ph.D. student who can receive 3 ECTS if he/she does not complete the final exam (in this case the attendance must be certified).
- If a Ph.D. student attends a 5-day conference presenting a scientific contribution, he/she will obtain 5 ECTS for the participation and additional 2 ECTS for the conference contribution (the certification is required for both the attendance and the presentation).

Please refer to the *"Educational regulations of the Doctoral School of Politecnico di Bari"* for more details http://www.poliba.it/sites/default/files/dottorati/regscudopoliba.pdf

The ECTS related to the **research activities** are divided into:

G. Individual research activity.
H. **Supervision of students:** tutoring activities for students in undergraduate and master's degree programs.
I. **Integrative teaching activities:** supplementary teaching activity (e.g., seminars, courses, practical exercises, etc.) for students in undergraduate and master's degree programs within the limit of 40 hours per academic year.
J. Preparation of manuscripts for conferences or journals.

Note that each ECTS usually corresponds to 25 hours of research activity.

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Fault detection techniques in condition monitoring: model-based and data-driven methods	March-April 2023	Yes	1
	Modeling and simulation of biological and medical systems	January-June 2023	Yes	3
	Attendance to at least two courses, according to the 2022/2023 syllabus, with a final exam	II semester 2022/2023	Yes	5
	Attendance to at least two courses related to the research program, with optional final exam	I and II semester 2022/2023	No	5
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	Applied Data-Driven Fault Diagnosis	Feb-March 2023		1.5
	Introduction to Fault Diagnosis and Prognosis	March-April 2023		1.5
	At least one seminar participation, depending on availability and topic.	I and II semester 2022/2023		3
E. Participation to international congresses or workshops	Human-Machine Collaboration 2022	1-2 December 2022		2
	At least two days' workshop participation, depending on availability and topic.	I and II semester 2022/2023		2
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			24
G. Individual research activity	Implementation of master's degree thesis project with a follow-up paper. Study of literature, according to the research program	I and II semester 2022/2023		26
H. Supervision of students	Supervision of Students under the guidance of the tutor	I and II semester 2022/2023		5
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	II semester 2022/2023		5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			36
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Attendance to at least two courses, according to the 2023/2024 syllabus, with a final exam	I and II semester 2023/2024	Yes	9

	Attendance to at least two courses related to the research program, with optional final exam	I and II semester 2023/2024	No	5
B. Master's degree courses				
C. Soft skill courses				
D. Participation to seminars	At least two seminars participation, depending on availability and topic.	I and II semester 2023/2024		3
E. Participation to international congresses or workshops	At least two days' workshop participation, depending on availability and topic.	I and II semester 2023/2024		4
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			21
G. Individual research activity	Research activity in the Artificial Intelligence and Predictive Maintenance field	I and II semester 2023/2024		27
H. Supervision of students	Supervision of Students under the guidance of the tutor	I and II semester 2023/2024		3
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	I and II semester 2023/2024		9
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			39
	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	At least one seminar participation, depending on availability and topic.			2
E. Participation to international congresses or workshops	At least two days' workshop participation, depending on availability and topic.			4
F. Presentation of research products at international congresses or workshops				
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			6

G. Individual research activity	Research activity in the Artificial Intelligence and Predictive Maintenance field	I and II semester 2024/2025		44
H. Supervision of students	Supervision of Students under the guidance of the tutor	I and II semester 2024/2025		3
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	Verbalization of the results obtained, in the form of a paper for a conference or a journal.	I and II semester 2024/2025		7
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			54
	TOTAL OF ECTS			**60**

Daniele ANTONUCCI

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Luca CONSOLINI