NATIONAL PH.D. PROGRAM IN AUTONOMOUS SYSTEMS

Intelligent systems to support dermatological medical decisions in the proximity healthcare framework

Ph.D. candidate

Simona Monfreda

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Tutors

Prof. Engr. Vitoantonio Bevilacqua, PhD

Prof. Engr. Antonio Brunetti, PhD

Engr. Giovanni Piccininno (Item Oxygen srl)

1. Description of the research program

The skin is recognized as the largest organ in the human body and plays a vital role in protecting against pathogens, controlling body temperature, and regulating hydration. Skin diseases, from mild irritations to chronic conditions, are a global health issue requiring an understanding of their causes, mechanisms, and optimal treatment strategies. Early diagnosis and treatment can improve patients' quality of life. The characterization of skin lesions, including those suspected of being cancerous, is carried out through histopathological examination and often requires an in-depth analysis by clinical experts using advanced instrumentation. Unfortunately, effectively diagnosing and treating skin pathological conditions, especially in remote areas, represents a significant challenge. Additionally, the shortage of specialized dermatologists in rural areas increases the risk of skin disease-related mortality and disability.

In recent years, the implementation of telemedicine services—i.e., the provision of medical care through telecommunications infrastructure and technologies—has undergone significant evolution, establishing itself as a fundamental component of modern healthcare. Among the various applications of telemedicine, proximity telemedicine stands out for its ability to improve healthcare accessibility, quality of care, cost-effectiveness, and overall patient satisfaction. However, the implementation of such a healthcare model requires the introduction of intelligent systems that support patients, healthcare workers, and caregivers in all phases of the care process.

In this context, teledermatology is an excellent example of how digital technology, using advanced algorithms for image acquisition and processing, can raise the quality of medical care. Since the inauguration of the first international teledermoscopy network, teledermoscopy has yielded significant outcomes in mass screening initiatives and in providing access to underserved regions distant from local dermatologists. The inclusion of clinical and dermoscopic images has been shown to increase the diagnostic accuracy of teledermatology by approximately 15%, adding only 1 to 2 minutes to the consultation time. Indeed, management correspondence between mobile teledermoscopy and face-to-face (FTF) assessments is generally positive, with full or partial diagnostic concordance between 81% and 91%. As care transitions from FTF to telemedicine appointments, teledermoscopic images should be used to improve the diagnostic accuracy of telemedicine visits, which are often less accurate than FTF encounters.

Recent studies indicate that intelligent systems, particularly those employing Machine Learning (ML) and Deep Learning (DL) methodologies, have the potential to serve as effective tools for the automatic analysis of medical images and videos aimed at identifying and characterizing skin lesions, enhancing diagnostic accuracy and efficiency, while offering critical support to clinicians. Advanced algorithms can optimize imaging procedures, improve data quality, and automate lesion characterization, aiding in more timely and targeted treatments. Additionally, they provide context-aware feedback, reducing effort for healthcare providers and optimizing healthcare resources and patient care quality.

The primary objective of this research program is to study, design, develop, and validate innovative methodologies for the integration of intelligent decision support systems and telemedicine within the framework of proximity healthcare, thereby necessitating the utilization of telemedicine services. To accomplish this objective, cutting-edge image processing algorithms and methodologies based on machine learning or deep learning will be modeled, focusing on ensuring high accuracy across the diverse phenotypes considered in the decision-making processes. Particular attention will be given to model explainability, incorporating interpretability techniques to make models transparent and understandable to healthcare professionals, thereby increasing trust and facilitating informed clinical decision-making.

Furthermore, the application of automated control mechanisms to manage and reduce the environmental impact of these systems is essential, as advanced healthcare technologies increasingly rely on substantial computational resources. The project will consider the energy and carbon footprint of the framework, investigating various ways to distribute and optimize the learning process and computational resources, thereby promoting a more sustainable approach to artificial intelligence in healthcare.

2. Schedule of the research activities

First academic year (planned)

	Description	Period	Activity abroad
Study and literature review on medical image analysis	Comprehensive analysis of available literature on medical image analysis and ML/DL methods for skin lesion characterization, focusing on explainable approaches. Identification of existing gaps and challenges.	6 months	NO
Study and literature review on telemedicine systems	Comprehensive analysis of available literature on telemedicine in dermatology. Identification of existing gaps and challenges.	3 months	NO
Data collection and preliminary analysis	Collect and analyze relevant images to identify patterns and establish parameters for automated lesion analysis.	3 months	NO

Second academic year (planned)

	Description	Period	Activity abroad
Architectural modeling of the decision support framework in proximity telemedicine	Architectural modeling and design of the framework for acquisition, analysis and characterization of medical images.	6 months within the company (01/11/2025 – 30/04/2026)	NO
Design and development of intelligent systems	Design and develop of intelligent systems, based on innovative approaches for acquiring, processing, and characterizing images. Identification and develop approaches for improving explainability of classification models.	6 months	NO

Third academic year (planned)

	Description	Period	Activity abroad
Optimization and validation	Optimization and validation of the framework to assess accuracy, ensure its effectiveness and reliability in real-world scenarios, and identify areas for improvement, also in a sustainable perspective.	6 months	NO
Abroad Project	TBD	6 months	YES, hosting University to be defined (01/05/2027 – 31/10/2027)

3. Training and research activities plan

First academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses	Intelligent Supervisory Systems	Jan 2025	Yes	2
	Machine learning (ScuDo courses)	Jan–Feb 2025	Yes	2
	Deep learning (ScuDo courses)	Feb 2025	Yes	2
	Human autonomous system interaction	Feb-Mar 2025	Yes	1
	Introduction to autonomous systems	Jun 2025	Yes	1
	Game Theory for controlling Autonomous Systems	Jun 2025	Yes	1
	Data-driven fault diagnosis and fault prognosis	Jul 2025	Yes	1
B. Master's degree courses	Big Data Analytics		Yes	6
C. Soft skill courses				
D. Participation to seminars	TBD			3
E. Participation to international congresses or workshops	GNB Annual School	Sep 2025		5
	TBD			5
F. Presentation of research products at international congresses or workshops	TBD			2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			31
G. Individual research activity				24
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals				5
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			29
	TOTAL OF ECTS			**60**

Second academic year (planned)

	Description	Period	Final Exam	ECTS
A. Ph.D. courses				
B. Master's degree courses	Fondamenti di telematica		Yes	6
C. Soft skill courses	TBD			3
D. Participation to seminars				
E. Participation to international	GNB Annual School			5
	TBD			5

congresses or workshops				
F. Presentation of research products at international congresses or workshops	TBD			2
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			21
G. Individual research activity				32
H. Supervision of students				
I. Integrative teaching activities				1.5
J. Preparation of manuscripts for conferences or journals				5.5
	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				
E. Participation to international congresses or workshops	TBD			3
F. Presentation of research products at international congresses or workshops	TBD			3
	TOTAL OF ECTS FOR TRAINING ACTIVITIES			6
G. Individual research activity				50
H. Supervision of students				
I. Integrative teaching activities				
J. Preparation of manuscripts for conferences or journals	TBD			4
	TOTAL OF ECTS FOR RESEARCH ACTIVITIES			54
	TOTAL OF ECTS			**60**

Simona MONFREDA

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Prof. Engr. Vitoantonio BEVILACQUA

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Prof. Engr. Antonio BRUNETTI

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Engr. Giovanni PICCININNO

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