UNIVERSITÀ DEGLI STUDI DI NAPOLI FEDERICO II

DOTTORATO DI RICERCA / PhD PROGRAM IN
INFORMATION TECHNOLOGY AND ELECTRICAL ENGINEERING

Activities and Publications Report

PhD Student: Alessandra Somma

Student DR number: DR995852

PhD Cycle: XXXVII
PhD Cycle Chairman: Prof. Stefano Russo

PhD program student's start date: 1/11/2021
PhD program student's end date: 31/10/2024

Supervisor: Prof. Alessandra De Benedictis

e-mail: alessandra.debenedictis@unina.it

PhD scholarship funding entity: University of Naples Federico II

General information

Alessandra received in year 2021 the Master Science degree in Computer Engineering from the University of Naples Federico II. She attended the curriculum in Computer Engineering within the PhD program in Information Technology and Electrical Engineering (ITEE). She received the grant from University of Naples Federico II.

Study activities

Attended Courses

Year	Course Title	Type	Credits	Lecturer	Organization
1st	Virtualization technologies and their applications	Ad hoc course	5	Dr. Luigi De Simone	ITEE
1st	Sicurezza dei Dati	MSc Course	9	Prof. Alfredo De Santis	University of Salerno
1st	Cambridge English C1	Other course	4.8	Prof. Geraint Thomas	Centro Linguistico di Ateneo (CLA)
1st	Imprenditorialità Accademica	Ad hoc course	4	Prof. Pierluigi Rippa (DII)	UNINA Polytechnic and Fundamental Sciences School
1st	Risk Assessment	MSc course	6	Prof. Alessandra De Benedictis	UNINA Polytechnic and Fundamental Sciences School
2nd	IoT Data Analysis	Ad hoc course	4	Dr. Raffaele Della Corte	ITEE
2nd	Semantic artifacts and multimedia knowledge graphs for bio-data integration	Ad hoc course	2	Dr. Cristiano Russo	ITEE
3rd	Ethics and AI	Ad hoc course	2.4	Prof. Guido Boella (UNITO)	Italian Society for Ethics of AI
3rd	Strategic Orientation for STEM Research & Writing	Ad hoc course	5	Dr. Chie Shin Fraser	ITEE

Attended PhD Schools

No PhD Schools attended.

Attended Seminars

Year	Seminar Title	Credits	Lecturer	Lecturer affiliation	Organization
1st	Cyber security in Akka Technologies	0.4	Dr. Luigi Villa	Akka Technologies	ITEE
1st	Threat Hunting Essentials	0.4	Group-IB	Group-IB	ITEE
1st	Threat Hunting Use-Cases	0.4	Group-IB	Group-IB	ITEE
1st	IEEE Authorship and Open	0.3	IEEE	IEEE	IEEE

1st	Access Symposium: Tips and Best Practices to Get Published from IEEE				
1st	Ciberconflitti e minacce per la pace e la stabilità internazionale. Riflessioni sulla guerra	0.4	Prof. S. P. Romano, Prof. G. Tamburrini	UNINA	Gruppo RUniPace
1st	Explainable Natural Language Inference	0.3	Dr. Marco Valentino	DIETI	ITEE
1st	An Introduction to Deep Learning for Natural Language Processing	0.2	Dr. Marco Valentino	DIETI	ITEE
1st	15th International Conference on the Quality of Information and Communications Technology	3			University of Castilla-La Mancha
2nd	Complex network systems: introduction and open challenges	0.4		Scuola Superiore Meridionale	Scuola Superiore Meridionale
2nd	Publish Open Access Articles with IEEE under the CARE CRUI Agreement	0.1			Eszter Lukács (IEEE Client Services Manager)
2nd	Cybercrime and Information Warfare: National and International Actors	0.4	Dr. Pierluigi Paganini	Cybaze SPA	DIETI
2nd	Privacy and Data Protection	0.4	Dr. Stefano Mele	Gianni & Origoni	DIETI
2nd	Sensor Webinar | 5G-Enabled IoT and Digital Twins: Cybersecurity and Resilience	0.4			Sensors
2nd	IEEE 2023 Smart World Concgress	1.9			University of Portsmouth
2nd	Ricerca e formazione nella società della transizione digitale	1	CINI	CINI	CINI
3rd	1st International Workshop on Dataspaces for Digital Twins of Cities Critical Infrastructures (DS4DTCCI)	0.6			University of Salento
3rd	Edoardo Giusto - Research past, present and future	0.2	Dr. Edoardo Giusto	UNINA	DIETI

Research activities

Alessandra Somma's research focused on advancing Digital Twin (DT) technology, specifically addressing the challenges of standardizing and formalizing DT software architectures to accelerate their adoption. Beginning with an extensive literature review, she examined whether best practices in software-system design were being applied to DTs. Based on her findings, she designed and documented a domain- and platform-independent Digital Twin architecture using the Views and Beyond method from the Software Engineering Institute, aligned with ISO 42010 standards. This architecture integrates key elements and relationships identified through her literature analysis.

Recognizing that data management and simulation models are the two core components of DTs, Alessandra Somma explored the use of Model-Driven methodologies in the DT context. Despite limited prior efforts in this area, existing approaches struggled to fully incorporate both data management and simulation, often missing critical elements.

Even if she investigated potential domains where DTs could provide significant benefits (healthcare, transportation, railways, and cybersecurity) her research led to the development of a Digital Twin platform aimed at enhancing urban mobility. This platform leverages a Model-Driven Architecture (MDA) approach, paving the way for future advancements in DT technology.

Tutoring and supplementary teaching activities

Alessandra Somma carried out tutoring and supplementary teaching activities within B.Sc. ("Calcolatori Elettronici") and M.Sc. courses ("Computer Systems Design", "Architetture dei Sistemi Digitali", "Risk Assessment") in the Computer Science programs at the University of Naples Federico II. Within these courses, Alessandra Somma prepared several seminar lectures and exercises.

Credits summary

PhD Year	Courses	Seminars	Research	Tutoring / Supplementary Teaching
1st	28.8	5.4	27	0.6
2nd	6	3.6	53	1.16
3rd	7.4	0.8	44	2.24

Research periods in institutions abroad and/or in companies

PhD Year	Institution / Company	Hosting tutor	Period	Activities
2nd	Montimage SRL	Wissam Mallouli, CTO	1/02/2023 – 31/07/2023	During six-month research, Alessandra Somma contributed to the DYNABIC European Project, focused on the enhancement of Critical Infrastructures' resilience through Cyber Digital Twins (CDTs). Research activities included the literature study of the application of Digital Twin technology in cybersecurity context,

				definition and development of the architectural CDT framework included in project D2.1 sensitive deliverable.

PhD Thesis

In PhD thesis, Alessandra Somma investigated Digital Twins (DTs) technology. DTs are dynamic virtual representations of physical assets or processes, distinguished by seamless bidirectional data flow between physical and digital spaces. This capability allows DTs to provide advanced services that go beyond traditional simulations, including enhanced monitoring, control, visualization, and the prediction of future states. By offering actionable insights, such as raising alerts or directly interacting with the physical system, DTs have emerged as a transformative technology across various sectors.

Despite the growing interest in DTs, a major challenge remains in the standardization and formalization of DT architectures, which are crucial for the design and development of software-intensive systems like DTs. The lack of standardized approaches has significantly hindered their development and widespread adoption. Many current DT architectures rely on ad-hoc approaches that deviate from established best practices in system design, reducing DTs to simple simulation models and overlooking essential features like bidirectional data flow.

To address these issues, the thesis proposes a three-step approach. First, a Systematic Mapping Study is conducted to review the existing literature on DT architectures, identifying key architectural elements, their relationships, and limitations. Second, the thesis adopts the Views and Beyond method, developed by the Software Engineering Institute and aligned with the ISO 42010 standard, to design and document a domain- and platform-independent *Digital Twin Software Architecture* (DTSA). The proposed architecture integrates the elements and relationships identified in the literature into a multi-view structure. Its completeness, usefulness, and perceived usability are evaluated through a validation survey involving experts from industry and academia.

Third, to tackle development challenges, the thesis introduces a *Model-Driven Architecture* (MDA) methodology based on the evaluated domain-agnostic DTSA, specifically for the development of a Mobility Digital Twin. Focused on the transportation domain, the MDA approach progresses from computational models to platform-specific models through automatic model-to-model transformation, facilitating increased reusability and flexibility.
To demonstrate the applicability of the MDA-based approach, the *Bologna Mobility Digital Twin* case study is presented, showcasing a platform built using *FIWARE* technology for context data management and *Simulator of Urban MObility* (SUMO) for simulation functionalities.

Research products

Research results appear in *5* papers published and *2* papers submitted and currently under review in international journals, *4* contributions to international conferences.

List of scientific publications

International journal papers

A. De Benedictis, N. Mazzocca, A Somma and C. Strigaro, Digital Twins in Healthcare: An Architectural Proposal and Its Application in a Social Distancing Case Study*, IEEE Journal of Biomedical and Health Informatics*, vol. 27 (10), pp. 5143-5154, 2023, DOI: 10.1109/JBHI.2022.3205506.

A. De Benedictis, F. Flammini, N. Mazzocca, A. Somma and F. Vitale, Digital Twins for Anomaly Detection in the Industrial Internet of Things: Conceptual Architecture and Proof-of-Concept*, IEEE Transactions on Industrial Informatics*, vol. 19 (12), pp. 11553-11563, 2023. DOI: 10.1109/TII.2023.3246983.

L. De Donato, R. Dirnfeld, A. Somma, A. De Benedictis, F. Flammini, S. Marrone, M. S. Azari and V. Vittorini, Towards AI-assisted digital twins for smart railways: preliminary guideline and reference architecture, *Journal of Reliable Intelligent Environments*, vol. 9, pp. 303–317, 2023. DOI: 10.1007/s40860-023-00208-6-

L. De Donato, R. Dirnfeld, A. Somma, M. S. Azari, S. Marrone, F. Flammini and V. Vittorini, Integrating AI and DTs: challenges and opportunities in railway maintenance application and beyond, *Simulation*, vol. 100 (9), pp. 903-917, 2024. DOI: 10.1177/00375497241229756.

A. Somma, A. De Benedictis, C. Esposito and N. Mazzocca, The convergence of Digital Twins and Distributed Ledger Technologies: A systematic literature review and an architectural proposal, *Journal of Network and Computer Applications*, vol. 225 (103857), 2024. DOI: 10.1016/j.jnca.2024.103857.

F. Rocco di Torrepadula, A. Somma, A. De Benedictis and N. Mazzocca, Smart Ecosystems and Digital Twins: an architectural perspective and a FIWARE-based solution, IEEE Software. Status: under review.

A. Somma D. Amalfitano, A. De Benedictis and N. Mazzocca, Advancing Digital Twin Architecture: A Unified Approach Integrating SEI Views and Beyond with ISO/IEC/IEEE 42010, *Journal of Systems and Software*. Status: under review.

International conference papers

A. De Benedictis, C. Esposito and A. Somma, Toward the Adoption of Secure Cyber Digital Twins to Enhance Cyber-Physical Systems Security, in *2022 International Conference on the Quality of Information and Communications Technology* (QUATIC), Talavera de la Reina, Spain, pp. 307-321, 2022. DOI: 10.1007/978-3-031-14179-9_21.

A. Somma, V. Casola, A. R. Cavalli, A. De Benedictis, W. Mallouli and V. E. Valdés, A Cyber Digital Twin Framework to Support Cyber-Physical Systems Security, in *2023 IEEE Smart World Congress* (SWC), Portsmouth, United Kingdom, pp. 1-10, 2023. DOI: 10.1109/SWC57546.2023.10449161.

A. Somma, A. De Benedictis, M. Zappatore, C. Martella, A. Martella and A. Longo, Digital Twin Space: The Integration of Digital Twins and Data Spaces, in *2023 IEEE International Conference on Big Data* (BigData), Sorrento, Italy, pp. 4017-4025, 2023. DOI: 10.1109/BigData59044.2023.10386737.

A. De Benedictis, F. Rocco di Torrepadula and A. Somma, A Digital Twin Architecture for Intelligent Public Transportation Systems: A FIWARE-Based Solution, in *2024 Web and Wireless Geographical Information Systems* (W2GIS), Yverdon-les-Bains, Switzerland, 2024. DOI: 10.1007/978-3-031-60796-7_12

Patents and/or spin offs
None.

Awards and Prizes
None.

Date <u>15.10.2024</u>

PhD student signature <u>Alessandra Somma</u>

Supervisor signature <u>Alessandra D. Benedict</u>