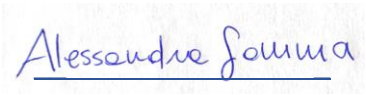
PhD in Information Technology and Electrical Engineering
Università degli Studi di Napoli Federico II

PhD Student: Alessandra Somma

Cycle: XXXVII

Training and Research Activities Report

Year: First



Tutor: prof. Alessandra De Benedictis

Date: October 31, 2022

Training and Research Activities Report

PhD in Information Technology and Electrical Engineering

Cycle: XXXVII **Author: Alessandra Somma**

1. Information:

- PhD student: Alessandra Somma
- DR number: DR995852
- Date of birth: 28/12/1996
- Master Science degree: Computer Engineering
  University: Università degli Studi di Napoli Federico II
- Doctoral Cycle: XXXVII
- Scholarship type: UNINA
- Tutor: Prof. Alessandra De Benedictis

2. Study and training activities:

Activity	Type[1]	Hours	Credits	Dates	Organizer	Certificate[2]
Cyber security in Akka Technologies.	Seminar	2	0.4	03/11/21	Prof. D. Cotroneo, Prof. S. P. Romano (DIETI)	Y
Threat Hunting Essentials.	Seminar	2	0.4	03/12/21	Prof. D. Cotroneo (DIETI)	Y
Threat Hunting Use-Cases.	Seminar	2	0.4	13/12/21	Prof. D. Cotroneo (DIETI)	Y
Neural Networks and Deep Learning	Course	95	9	01-05/22	Prof. G. Buttazzo (SSSA)	N
Virtualization technologies and their applications	Course	20	5	17/01/22-18/02/22	Dr. Luigi De Simone (DIETI)	Y
Sicurezza dei Dati	Course	72	9	02-03/22	Prof. Alfredo De Santis (UNISA)	Y
IEEE Authorship and Open Access Symposium: Tips and Best Practices to Get Published from IEEE	Seminar	1.5	0.3	30/03/22	IEEE	Y
Ciberconflitti e minacce per la pace e la stabilità internazionale. Riflessioni sulla guerra in Ucraina e oltre.	Seminar	2	0.4	05/04/22	Prof. S. P. Romano. Prof. Tamburrini	Y
Towards a political philosophy of AI	Seminar	2	TBD	11/04/22	Mark Coekelberg	N

(Picariello Lectures)					h	
Explainable Natural Language Inference.	Seminar	1.5	0.3	13/04/22	Dr. M. Valentino	Y
An Introduction to Deep Learning for Natural Language Processing	Seminar	1	0.2	13/04/22	Dr. M. Valentino	Y
Big Data Architecture and Analytics	Course	20	5	06/04/22-11/05/22	Prof. G. Sperlì (DIETI)	N
Cambridge English C1	Course	24	4.8	17/02/22-05/05/22	CLA	Y
Risk Assessment	Course	48	6	03-06/22	Prof. A. De Benedictis (DIETI)	Y
A day in the life of a Chief Data Officer	Seminar	2	TBD	9/05/2022	Prof. Maranca	N
Imprenditorialità Accademica	Course	16	4	26/05/22 - 14/06/22	Prof. P. Rippa	Y
15th International Conference on the Quality of Information and Communications Technology	Seminar	15	3	12-14/09/22		Y

1) Courses, Seminar, Doctoral School, Research, Tutorship
2) Choose: Y or N

2.1. Study and training activities - credits earned:

	Courses	**Seminars**	**Research**	**Tutorship**	**Total**
Bimonth 1	0	1.2	6	0	7.2
Bimonth 2	0	0	6	0	6
Bimonth 3	14	1.2	4	0.4	19.6
Bimonth 4	10.8	0	6	0	16.8
Bimonth 5	4	0	2	0.2	6.2
Bimonth 6	0	3	3	0	6
Total	**28.8**	**5.4**	**27**	**0.6**	**62**
Expected (1st year)	**20 - 40**	**5 - 10**	**10 - 35**	**0 – 1.6**	
Expected	**30 - 70**	**10 - 30**	**80 - 140**	**0 – 4.8**	

3. Research activity:

The main research topic which I focused on during my first year is the Digital Twin (DT), *i.e.*, "*a dynamic and self-evolving virtual representation of a physical entity of real space and it is characterized by a bi-directional communication that allows real-time data sharing between physical and digital equivalents*" [1]. Thus, the Digital Twins (DTs) are virtualized assests (*e.g.*, products, machine tools), processes (*e.g.*, finance, supply chain, human resources) or systems (*e.g.*, entire production plants or buildings) that can be formalized as the following quintuple [2]:

$$M_{DT} = (PS, VS, Ss, DD, CN)$$

where i) the *Physical Space* (PS) consists of real entities and their internal and external interactions; ii) the *Virtual Space* (VS) contains the digital replicas, fed with real-time data obtained from the physical world combined with historical data; iii) the *DT Data* (DD) are Digital Twin fuel, gained from domain experts, the physical world and/or generated through virtual models and DT-based services; iv) the virtual mirroring allows a rapid access to the properties of real-world entity and therefore enables a wide set of *Services* (Ss) offered, *e.g.*, simulation, maintenance, correction of issues, optimization of new or existing assets, prediction of the physical entity future states; v) finally, there are the *Connections* (CN) that enable the cooperation between the four parties.

Introduced over a decade ago as an innovative all-encompassing tool, the Digital Twin has several benefits, *e.g.*, cost, time and resource reducing of prototype producing and testing, monitoring a physical asset in real time and getting alerts before something goes critically wrong, accurate forecasting. Moreover, the virtual counterpart can act like a shadow, thus the information collected by a DT can be further analyzed to better develop future products, processes or systems in less time and at a lower cost.

Although the concept of DT has been around for nearly twenty years, industrial and academic interest in this field has only recently developed, and even if the number of successful implementation is currently increasing (*e.g.*, "The SIMULIA Living Heart" Project[1]), details are not publicly available. This led to a delay in the widespread implementation and adoption of Digital Twins that is due to [3]: i) the DT is still a fast evolving concept; ii) the lack of a universal DT reference framework; iii) problem and domain-dependence; iv) security concerns over shared data; v) lack of DT performance metrics; vi) reliance of DT on other fast-evolving technologies, mainly Internet of Things (IoT), Big Data and Machine Learning.

My research activity has been primarily focused on investigating the architectural aspects of DT implementation, as Software Architectures (SAs) are fundamental in the engineering process of software-intensive systems such as DTs. In this regard, starting from an in-depth analysis of the state-of-the-art on DT framework proposal and applications, I have proposed a layered software architecture integrating all relevant DT functionalities and services, according to the Autonomic Computing (AC) MAPE-K (*i.e.*, *Monitor-Analyze-Plan-Execute* over a shared *Knowledge* base) feedback loop. In fact, due to the increasing complexity, uncertainty and dynamicity of software systems, MAPE-K is a well recognized engineering approach to deal with highly changing operational conditions (*e.g.*, components can appear and disappear, may become temporarily or permanently unavailable or change their behavior) and thus to increase self-adaptation capability of the physical twin, *i.e.*, the system ability to modify its behavior and/or structure in response to its perception of the environment and the system itself [5].

More in detail, a *self-adaptive software system* consists of two layers, *i.e.*, the managed subsystem, comprising the application logic, and the managing subsystem (autonomic manager), on top of the managed subsystem, comprising the adaptation logic, that realizes the feedback loop. Based on the knowledge about the managed subsystem, the autonomic manager monitors the managed element and its external environments; starting from the analysis of gained information, the manager subsystem constructs and executes plans, relieving humans of the responsibility of directly managing the managed subsystem, thus increasing its autonomy and self-adaptation. It is clear that the managed subsystem is what in DT concept is defined the real twin and the autonomic manager is the Digital Twin itself.

[1] https://www.3ds.com/products-services/simulia/solutions/life-sciences-healthcare/the-living-heart-project/

According to the MAPE-K feedback loop approach, the autonomic manager needs: 1) a component Knowledge (K) that maintains data of the managed subystem and environment, and other relevant states; 2) a component Monitor (M) that gathers and eventually pre-processes data from the underlying managed subsystem through sensors; 3) a component Analyse (A) that performs data analysis to check whether an adaptation is required; 4) a component Plan (P) triggered by the Analyse one, that identifies the workflow of actions necessary to achieve the system's goals; 5) a component Execution (E) that carries out these actions through actuators of the managed subsystem. Starting from this, the software architecture is characterized by:

1. Physical Twin Layer
2. Data Layer
3. Digital Twin Layer
4. Service Layer
5. Connectivity Layer

In Data-Digital Twin-Service levels, there is the set of functionalities that allows to build the Digital Twin in accordance with the methodology. Each functionality can be implemented with one or more components; therefore, the Monitor, Analyse, Plan, and Execute phases may be performed by multiple components cooperating in a decentralized manner: regardless of how those control components are physically distributed, they will synchronize to drive PT adaptation when need.

The suitability of the proposed architecture has been demonstrated by means of a real-life industrial case study developed by Hitachi Rail that provides social distance monitoring via a DT-based approach and by means of a DT-based anomaly detection service in railway context.

Finally, during the last period of my first year, I started to investigate Digital Twin security issues and applications for security purposes. In fact, with a preliminary literature study, I found out that Digital Twin usage for security (*e.g.*, intrusion detection) identifies the so-called Cyber Digital Twin (CDT) [6]. On the other hand, since physical and virtual replicas live side by side in complex ecosystems, the need for secure and trustworthy DTs arises. In order to cope with this issue, I am exploring the integration of Distributed Ledger Technologies (DLTs) into the proposed DT architecture.

3.1. References:

[1] M. Singh, E. Fuenmayor, E. P. Hinchy, Y. Qiao, N. Murray and D. Devine, "Digital Twin Origin to Future," in *Appl Syst Innov*, vol. 4, no. 2, 2021, 10.3390/asi4020036.
[2] Q. Qi, F. Tao, T. Hu, N. Anwer, A. Liu, Y. Wei, L. Wang and A.Y.C. Nee, "Enabling technologies and tools for digital twin," in *J Manuf Syst*, vol. 58, pp. 3-21, 2021, 10.1016/j.jmsy.2019.10.001.
[3] A. Sharma, E. Kosasih, J. Zhang, A. Brintrup, A. Calinescu, "Digital Twins: State of the art theory and practice, challenges, and open research questions," in *J Ind Inf Integr*, vol. 30, 2022, 10.1016/j.jii.2022.100383.
[4] E. Ferko, A. Bucaioni and M. Behnam, "Architecting Digital Twins," in *IEEE Access*, vol. 10, pp. 50335-50350, 2022, 10.1109/ACCESS. 2022.3172964.
[5] L. F. Rivera, M. Jimenez, N. Villegas, G. Tamura, and H. A. Muller, "The forging of autonomic and cooperating digital twins," in *IEEE Internet Computing*, pp. 1–1, 2021.
[6] D. Holmes, M. Papathanasaki, L. Maglaras, M. A. Ferrag, S. Nepal and H. Janicke, "Digital Twins and Cyber Security – solution or challenge?," in *2021 6th South-East Europe Design Automation, Computer Engineering, Computer Networks and Social Media Conference* (SEEDA-CECNSM), 2021, pp. 1-8, 10.1109/SEEDA-CECNSM53056.2021.9566277.

4. Research products:

De Benedictis, A., Esposito, C., Somma, A., "Toward the adoption of secure Cyber Digital Twins to enhance Cyber-Physical Systems security", *15th International Conference on the Quality of Information and Communications Technology*. Status: published (https://doi.org/10.1007/978-3-031-14179-9_21).

De Benedictis, A., Mazzocca, N., Somma, A., Strigaro, C. (2022). "Digital Twins in Healthcare: an architectural proposal and its application in a social distancing case study", *Journal of Biomedical and Health Informatics* (JBHI). Status: published (https://doi.org/10.1109/JBHI.2022.3205506).

De Benedictis, A., Flammini, F., Mazzocca, N., Somma, A., Vitale, F., "A Digital Twin Architecture for Anomaly Detection in the Industrial Internet of Things", *IEEE Transactions on Industrial Informatics* (TII). Status: under 2nd stage of review.

5. Conferences and seminars attended:

Workshop Nazionale per il Trasferimento Tecnologico e l'Alta Formazione. Verona. 16-17/06/2022. I presented the poster entitled "Digital Twins: innovative applications, open challenges and architectural aspects".

15th International Conference on the Quality of Information and Communications Technology. QUATIC. Talavera de la Reina. 12-14/09/2022. I presented the work entitled "Toward the adoption of secure Cyber Digital Twins to enhance Cyber-Physical Systems security".

6. Activity abroad:

None.

7. Tutorship:

"*Computer System Design*" course: support and tutorship on Motorola 6800 programming and simulation on ASIM/ASIM Tool 22/03/2022 (3 hours); Intel 6821 peripheral driving programming 12/04/2022 (2 hours); Mutual exclusion in assembly 26/04/2022 (2 hours).

"*Calcolatori Elettronici 1*" course: exercise on sequential circuit design 13/04/2022 (2h); support for exams (5h).