



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

PhD Student:

Cycle: XXXIX

Training and Research Activities Report

Academic year: 2024-2025 - PhD Year: Second

student signature

Deboza, Russo

Tutor: prof. Nicola Mazzocca

tutor signature

Co-Tutor:

Date: 11/11/2025

Training and Research Activities Report

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Cycle:

Author:

1. Information:

- **PhD student:** Debora Russo **PhD Cycle:** XXXIX
- **DR number:** DR997211
- **Date of birth:** 01/07/1993
- **Master Science degree:** Computer Engineering **University:** University of Naples Federico II
- **Scholarship type:** PNRR – Partenariato Esteso PE 14 - RESTART
- **Tutor:** Nicola Mazzocca
- **Co-tutor:**
- **Period abroad:** *list research institutions, public administrations and/or companies and number of months spent/to be spent there*

2. Study and training activities:

Activity	Type ¹	Hours	Credits	Dates	Organizer	Certificate ²
QUIC: the secure protocol shaping the future of real-time communication over the Internet	Seminar	4	0.8	09-11/12/2024	Simon Pietro Romano	Y
Infrastructure Security: Threat and Model-based Automated Penetration Testing	Seminar	2	0.4	10/12/2024	Massimiliano Rak	Y
Shaping Robustly Control Loop: Look Into Stability Margins & Uncertainties –	Seminar	1	0.2	05/12/2024	Ciro Visone	Y
5G & Digital Transformation: a View From an Unconventional Perspective	Seminar	4	0.8	14/03/2025	5G Academy	Y
Sovranità digitale - cos'è e quali sono le principali minacce al cyberspazio nazionale	Seminar	1.5	0.3	23/06/2025	Marcello Cinque	Y
How to Boost your PhD	Course	18	5	08-15-22-29/01/2025 05-	Antigone Marino	Y

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				12/02/2025		
20th TAROT Summer School on Software Testing, Verification & Validation	Course	24	4.8	June 30 - July 4, 2025	Valentina Casola	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		1,4	8.6		10
Bimonth 2	5		5		10
Bimonth 3		0.8	9.2		10
Bimonth 4		0.3	9.7		10
Bimonth 5	4.8		5.2		10
Bimonth 6			10		10
Total	9.8	2.5	47.7		60
Expected	30 - 70	10 - 30	80 - 140	0 - 4.8	

3. Research activity:

During the second PhD year, the research advanced from the dynamic modeling of urban mobility toward the perceptual and physical representation of the built environment, consolidating the methodological foundations of synthetic data generation for smart city applications.

This phase aimed at bridging the gap between behavioral simulations (traffic dynamics, agents, network anomalies) and perceptual simulations (materials, geometry, and physical interactions), through the development of interoperable pipelines and multimodal datasets.

The work evolved along three main directions:

- **Consolidation of the Behavioral Layer.**
The previously developed SynthCityUnreal toolbox was refined to enable the generation of reproducible urban mobility scenarios derived from GTFS data and OpenStreetMap networks. The system integrates origin–destination matrices, rerouting logic, and anomaly injection (e.g., metro strikes, road closures) in SUMO, allowing the export of dynamic trajectories and congestion indicators.
The resulting framework provides a robust foundation for large-scale testing of mobility policies and urban planning strategies.
- **Development of the Perceptual and Physical Layer.**
The core effort of this year was the creation of **UR-MAT**, a Material-Aware Synthetic Dataset that introduces physical realism into synthetic urban environments.
The pipeline combines OpenStreetMap-based geometry (processed in Blender via BLOSM) with physically-based rendering (PBR) in Unreal Engine 5, supporting the generation of RGB, depth, segmentation, and metadata modalities through UnrealCV.

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A dedicated JSON catalogue links each mesh to its material class (e.g., glass, concrete, limestone) and to electromagnetic parameters derived from ITU-R P.2040-3 (permittivity, conductivity, reflectance).

The dataset currently includes seven European districts, over 14 material classes, and multimodal frame captures for AI-based material segmentation and propagation modeling.

Experimental results achieved ~80% mIoU in material segmentation tasks using SegFormer and CLIP-based recognition.

- **Architectural Modularity and Future Integration.**

The research extended toward the design of **UR-MAT++**, a modular software architecture supporting automatic PBR assignment (AutoPBR) and dataset scaling to new cities.

The modules for alignment (OSM → SUMO → Blender → Unreal) were formalized, enabling bidirectional exchange of geometry and traffic data.

This modularity will allow, in the third year, the integration of behavioral dynamics (from SynthCityUnreal) into the material-aware 3D environment, paving the way for unified simulation and AI reliability testing within the upcoming Fortiss/TUM research period (2026).

4. Research products:

[J1]	<i>D. Russo, F. Rocco Di Torrepadula, L. Libero Lucio Starace, S. Di Martino and N. Mazzocca, "A Framework for Generating Synthetic Urban Mobility Datasets With Customizable Anomalous Scenarios," in IEEE Open Journal of Intelligent Transportation Systems, vol. 6, pp. 1439-1458, 2025, doi: 10.1109/OJITS.2025.3626948.</i>
[C1]	<i>D. Russo, D. Amalfitano, G. Di Martino, N. Mazzocca and V. Vittorini, "Material-Aware Synthetic Data Generation for Smart City Applications," 2025 IEEE International Conference on High Performance Computing and Communications (HPCC), Exeter, United Kingdom, 2025, pp. 1037-1044, doi: 10.1109/HPCC67675.2025.00151</i>
[C2]	<i>Debora Russo, Nicola Mazzocca, and Valeria Vittorini. 2025. UR-MAT: A Multimodal, Material-Aware Synthetic Dataset of Urban Scenarios. In Proceedings of the 33rd ACM International Conference on Multimedia (MM '25). Association for Computing Machinery, New York, NY, USA, 13164–13169. https://doi.org/10.1145/3746027.3758314</i>
[D1]	<i>Russo, D. (2025). SynthCity Case Study – Genoa, Italy [Data set]. Zenodo. https://doi.org/10.5281/zenodo.17517746</i>

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[D2]	Russo, D. (2025). UR-MAT: A Multimodal, Material-Aware Synthetic Dataset of Urban Scenarios [Data set]. Zenodo. https://doi.org/10.5281/zenodo.16748119
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J – Journal Paper; C – Conference Paper; D – Dataset

5. Conferences and seminars attended

- *RESTART Plenary Dissemination Workshop, Napoli 30 June- 1st July 2025*
- *23rd IEEE International Conference on Smart City (SmartCity-2025), Exeter 13-15 August 2025. Presented the paper: D. Russo, D. Amalfitano, G. Di Martino, N. Mazzocca and V. Vittorini, "Material-Aware Synthetic Data Generation for Smart City Applications,"*
- *33rd ACM International Conference on Multimedia (ACMMM2025), Dublin 27-31 October 2025. Presented the paper: Debora Russo, Nicola Mazzocca, and Valeria Vittorini. 2025. "UR-MAT: A Multimodal, Material-Aware Synthetic Dataset of Urban Scenarios".*

6. Periods abroad and/or in international research institutions

7. Tutorship

8. Plan for year three

*During the third PhD year (Nov 2025 – Oct 2026), the research will focus on the **integration and validation** of the two layers developed so far — the behavioral (mobility) and perceptual (material-aware) layers — within a unified synthetic-simulation framework for smart-city environments.*

Planned research activities

- **Unified simulation and testing.**
Extend the existing UR-MAT++ architecture by coupling the SynthCityUnreal mobility module with the material-aware 3D environments, enabling cross-domain experiments where vehicle dynamics and physical perception coexist in the same synthetic urban twin. Validation will include metamorphic-testing scenarios for AI perception models and explainability analyses based on synthetic anomalies.
- **AutoPBR and material-aware scaling.**
Finalize the AutoPBR system for automatic PBR material assignment using CLIP/BLIP-based semantic recognition and rule-based physical modeling; expand the dataset to additional European districts and new material categories.
- **Integration with electromagnetic simulators.**
Employ NVIDIA Sionna RT for signal-aware ray-tracing simulations over the UR-MAT++ scenes to study the effect of materials on 5G/6G propagation and sensing tasks.

International research period

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- **Fortiss / Technical University of Munich (Germany)** – November – April 2026.
Research stay under the supervision of Dr. Andrea Stocco, focused on Reliability through Synthesis: metamorphic testing, explainability, and reliability evaluation of perception models in synthetic urban twins..

Draft thesis title

“Synthetic Data Generation for Smart City Applications: From Behavioral Simulation to Reliable AI Perception”