Faculty Member Contact Information

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Contact Info	
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2 Unfunded URCA Assistant(s)

Are you willing to work with students from outside of your discipline? If yes, which other disciplines?

- No

How many hours per week will your student(s) be required to work in this position?
(Minimum is 6 hours per week; typical is 9)

- 6

Will it be possible for your student(s) to earn course credit?

- No

Location of research/creative activities:

- No specific location

Brief description of the nature of the research/creative activity?

- *Project Title:* Developing a High-Fidelity Co-Simulation Digital Twin for Autonomous Vehicle Research
- *Project Description:* This research project focuses on developing a robust co-simulation ecosystem of digital twin tools to advance active Autonomous Vehicle (AV) communication and security research. Because testing connected and autonomous vehicles in the real world is inherently dangerous and costly, we require high-fidelity simulation environments. This project utilizes the industry-standard CARLA autonomous driving simulator (https://carla.org/), built upon Unreal Engine, as our foundational open canvas. However, CARLA does not inherently guarantee physical accuracy out of the box. We must build the precise physical and systemic models necessary to transform this sandbox into a rigorous, research-ready environment. Furthermore, we leverage

CARLA's built-in ROS2 bus to integrate external co-simulation tools — such as ns-3 (https://www.nsnam.org/) for network communications, SUMO (https://eclipse.dev/sumo/) for macro-traffic modeling, and CAN bus simulators (e.g. SocketCAN https://docs.kernel.org/networking/can.html) — to create a comprehensive, hyper-realistic digital twin ecosystem.

- *Project Significance and Research Opportunities:*

- Advanced Game Engine API Utilization: Researchers will not solely operate the simulation but will deeply engage with the CARLA API to programmatically control the underlying Unreal Engine. This involves manipulating physics, environmental variables, and rendering pipelines to serve specific scientific research objectives.

- Automotive Cybersecurity Testing Environment: As real AV hardware is cost-prohibitive and dangerous to compromise, our digital twin provides a highly resilient testing environment. By integrating Electronic Control Unit (ECU) simulators, the project offers a safe, isolated platform for automotive reverse engineering and penetration testing. Researchers will analyze sensor spoofing, malicious CAN frame injection, and adversarial attacks to develop robust defensive systems.

- Interdisciplinary Research Application: This project operates at the dynamic intersection of multiple technical domains. Researchers will gain practical experience spanning robust Software Engineering (architecting the simulation toolchain), Cybersecurity (penetration-testing vehicular networks), and Machine Learning & AI (evaluating computer vision and autonomous navigation algorithms within the simulation).

Brief description of student responsibilities?

- *Undergraduate Research Role and Responsibilities:*
- Undergraduate researchers will tackle hands-on, systems-level software engineering to expand our simulation capabilities. The student will bridge the gap between a standard game engine and a physically accurate autonomous systems research tool.
- *The student will execute the following core objectives:*

- Enhance Physical Realism: Develop and integrate custom physics and environmental models into the CARLA engine. For example, researchers will program dynamic road friction adjustments corresponding to weather changes, and implement advanced sensor degradation models. This includes overcoming default camera module limitations by introducing dynamic motion blur and ghosting effects dependent on vehicle velocity, alongside simulating Lidar scattering and lens obstruction during adverse weather conditions.

- Integrate Co-Simulation Tools: Utilize the ROS2 architecture to seamlessly connect CARLA with external simulators (ns-3, SUMO, CAN bus tools) to increase the overall fidelity of the AV communication network and traffic environment.

- Develop a Custom Scenario Runner: Architect and program a robust scenario execution engine from the ground up to parse, interpret, and execute complex traffic and environmental scenarios defined in the emerging OpenSCENARIO 2.1 format.

- Execute Security and Penetration Testing: Utilize simulated ECUs and the co-simulation network to model cyber-attacks. Test and benchmark the integrated simulation ecosystem to ensure high-fidelity replication of real-world AV security vulnerabilities and communication use cases.

- *Required Qualifications & Skills*
- This project demands a systems-centric approach and requires a strong foundation in computer science. Ideal candidates possess:

- Strong proficiency in C++ and Python programming languages.

- A genuine appetite and enthusiasm for systems-type research, complex software architecture, and solving physical simulation challenges.

- Familiarity with, or a strong desire to learn, the ROS2 framework and ecosystem.

- An interest in utilizing game engines (UE4) for advanced scientific simulation, robotics, and cybersecurity.

URCA Assistant positions are designed to provide students with *research or creative activities* experience. As such, there should be measurable, appropriate outcome goals. What exactly should your student(s) have learned by the end of this experience?

- Learning Outcomes and Professional Development:
- Students will gain invaluable experience at the intersection of game development technology, physical modeling, and automotive cybersecurity. By manipulating APIs and reverse-engineering vehicular networks, this project fully prepares them for advanced research or industry roles in robotics, software engineering, systems security, and multi-domain simulation.
- Professional Differentiation: Furthermore, this experience serves as a powerful professional portfolio builder. Rather than possessing standard classroom coding experience, students will graduate with a highly marketable, cross-domain background—spanning systems architecture, AI integration, and cybersecurity—that distinguishes them as highly capable candidates for competitive technical and research positions.

<u>Requirements of Students</u>

If the position(s) require students to be available at certain times each week (as opposed to them being able to set their own hours) please indicate all required days and times:

- Regular working hours during Monday through Friday

If the location of the research/creative activities involves off campus work, must students provide their own transportation?

- Location is on-campus.

Must students have taken any prerequisite classes? Please list classes and preferred grades:

- Yes. These are ideally Junior and/or Senior level students. Ideally students who have already taken CS447 Networks and Data Communication but at minimum CS 314 Operating Systems.

Other requirements or notes to applicants: