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Ph.D. DISSERTATION DEFENSE

Candidate:	**Weihan Wang**
Degree:	**Doctor of Philosophy**
School/Department:	**Charles V. Schaefer, Jr. School of Engineering and Science / Computer Science**
Date:	**Thursday, Nov 21, 2024**
Time/Location:	**1:00 p.m., GN 421**
Title:	**Monocular and Binocular Visual-Inertial System Initialization and Real-time Dense 3D Mapping**
Chairperson:	**Dr. Philippos Mordohai, Department of Computer Science, Stevens Institute of Technology**
Committee Members:	**Dr. Enrique Dunn, Department of Computer Science, Stevens Institute of Technology** **Dr. Nikhil Muralidhar, Department of Computer Science, Stevens Institute of Technology** **Dr. Ioannis Rekleitis, Computer Science & Engineering Department, University of South Carolina**

ABSTRACT

Visual-Inertial Simultaneous Localization and Mapping (VI-SLAM) systems encounter considerable challenges in demanding environments, making advancements in this area crucial. Integrating a single camera with an Inertial Measurement Unit (IMU) in Visual-Inertial Navigation Systems (VINS) offers a cost-effective, low-power solution suitable for robot perception and AR/VR applications. The camera captures rich environmental details, while the IMU measures acceleration and angular velocity, enhancing system resilience in fast-motion or low-texture scenarios. This sensor fusion allows for complementary benefits, though achieving precise and dense 3D reconstruction in challenging conditions remains an unresolved issue.

This dissertation introduces methods to enhance both accuracy and robustness through two different IMU initialization techniques. It also presents a real-time 3D reconstruction pipeline tailored for VI-SLAM systems on resource-limited devices and proposes a complete VI-SLAM system with dense reconstruction capabilities by leveraging 3D Gaussian Splatting. Key contributions include (1) A fast, precise, and robust monocular visual-inertial initialization method utilizing an Error-State Kalman Filter (ESKF) to improve accuracy in challenging environments. (2) An extended initialization method for stereo visual-inertial SLAM, significantly enhancing both accuracy and robustness. (3) A real-time 3D reconstruction pipeline optimized for resource-constrained Autonomous Underwater Vehicles (AUVs). (4) An online Visual-Inertial Gaussian Splatting SLAM system featuring dense reconstruction.