



Ph.D. DISSERTATION DEFENSE

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Degree: Doctor of Philosophy
School: Charles V. Schafer School of Engineering and Science (SES)
Department: Mechanical Engineering (ME)
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Title: Advancing Combat Casualty Care: Grasping, Manipulation, and End-effector Design

Chairperson: Dr. Long Wang, Department of Mechanical Engineering, SES

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ABSTRACT

Rescue robots are critical in emergency situations, operating where human intervention is unsafe or difficult. Despite significant research in this field on perception, localization and mapping, two gaps hinder their development for casualty care and extraction: 1) an intelligence gap in ensuring safe and effective casualty manipulation, and 2) a lack of hardware specialized for handling medical equipment and assisting in emergency procedures. This work presents novel methodologies and tools to enable robotic systems to perform casualty care and rescue tasks.

To address the first gap, we developed a high-fidelity casualty manipulation simulation framework using a finite element method (FEM) to simulate biomechanical responses of the human musculoskeletal system, in order to support future robotic planning and control. This framework enabled the study of more realistic soft contacts and grasping stability on casualty limbs. To tackle the second gap, we repurposed the simulation framework for design and validation of a robotic end-effector specialized for emergency medical care. Finally, to enable future real-time field deployment, we introduced an analytical-model-informed neural network architecture to predict the nonlinear stiffness behavior of an underactuated robotic hand during tool handling. Beyond task-level prediction, this approach advances physically interpretable learning for robotic manipulation, supporting more reliable and safer autonomous tool-use behavior.