# Towards Resiliency in Cyber-physical Systems for Robot-assisted Surgery Poster.pdf

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A detailed analysis of the adverse events associated with the surgical robots (reported to the FDA) indicates that despite the increased number of robotic procedures and their greater utilization, the rate of adverse events has remained relatively steady over the last 14 years. Even though current surgical robots are designed with safety mechanisms in mind, in practice several significant challenges exist in enabling timely and accurate detection and mitigation of incidents during surgery. This project has the potential to transform fundamentally our understanding of the causes of incidents during robotic surgical procedures and their impact on patients, and thereby to promote the development of tools and techniques for design and validation of the next generation of resilient surgical robots. Toward this goal, the project will address (i) an in-depth analysis of incident causes, which takes into account the interactions among the system components, human operators, and patients; (ii) resiliency assessment of the robotic systems in the presence of realistic safety hazards, reliability failures, and malicious tampering; and (iii) continuous monitoring for detection of safety, reliability, and security violations to ensure patient safety.

The intellectual merit of this work lies in: (i) systems-theoretic approach driven by real data on safety hazards and medical equipment recalls, to identify causes leading to violation of safety constraints at different layers of the cyber and physical system-control-structure; (ii) creation of a unique safety hazard simulation engine to perform injections into robot control software and emulate realistic safety hazard scenarios in a virtual environment; (iii) an adaptive method for rapid detection of events that lead to safety violations, based on continuous monitoring of human operator actions, robot state, and patient status, in conjunction with a probabilistic graph-model that captures dependencies between the causal factors leading to safety hazards; and (iv) experimental validation using the real robot to assess monitoring and protection mechanisms in the presence of realistic safety hazards, reliability faults, and security exploits (recreated using safety hazard simulation engine).

The broader impact of the project is a methodology for design and resiliency assessment of a larger class of control cyber-physical systems, which involve humans in the on-line decision making loop. Application of the methodology to robot-assisted surgery demonstrates the strength and practicality of the approach and is likely to attract interest from areas of academia and industry in which cyber-physical systems are either a subject of study or the basis for delivering a service (e.g., transportation or electric power grids). This project's educational outreach encompasses strategies for broadening participation in multi-disciplinary projects spanning medicine and engineering.

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