Thesis Project Portfolio

Dexterity: Robotic Armature for Hazardous Materials Manipulation Operated via Haptic Interface Glove

(Technical Report)

Analysis of the Fukushima Daiichi Nuclear Power Plant in Disaster Crisis Response

(STS Research Paper)

An Undergraduate Thesis

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Sociotechnical Synthesis

My technical project and STS research are both within the sphere of teleoperated robotics used to interact with hazardous environments. The technical project, Dexterity, showcases a teleoperated system consisting of a robotic hand controlled by a haptic glove. This allows user to maneuver the robotic hand remotely while maintaining a sense of their surroundings through tactile feedback, which serves to be useful in a laboratory setting. The STS research analyzes the effectiveness of the disaster response of the Daiichi Nuclear Power Plant disaster in Fukushima, Japan, which involved the use of teleoperated drones to assist in the investigative and cleanup efforts of the reactor site. Together, the technical project and STS research illustrate the approach and effectiveness of implementing teleoperated systems to facilitate the handling of hazardous materials.

With an increasing demand for safe, cost-effective laboratory equipment for smaller labs, Dexterity presents a remotely operated robotic system designed for safe interaction with hazardous substances. The wireless system, modeled after the open-source DexHand project, consists of a haptic glove equipped with finger-tracking sensors and inertial measurement units (IMUs), which capture real-time hand and wrist movement data. This input wirelessly drives a robotic hand to mimic the user's motions with high fidelity. To enhance realism and control, each robotic fingertip contains a force-sensing resistor (FSR) that detects contact pressure and relays it to corresponding linear resonant actuators (LRAs) embedded in the glove, providing proportional vibrational haptic feedback to the user. The primary innovation of this system lies in its affordability, accessibility, and real-time control. Unlike expensive commercial alternatives, this prototype utilizes open-source hardware and custom-designed PCBs to deliver advanced functionality at significantly reduced cost, making it viable not only for research labs but also educational institutions and field applications. By enabling intuitive, remote manipulation of hazardous materials, Dexterity bridges the gap between high-performance robotics and practical safety tools, offering a scalable solution with implications for laboratory safety, remote exploration, and industrial automation.

My STS research analyzes the Fukushima Daiichi nuclear disaster through the lens of Actor-Network Theory (ANT), with a focus on the intertwined relationships between human and non-human actors during the crisis response. The study examines how the Tokyo Electric Power Company (TEPCO), the Japanese government, unmanned aerial vehicles (UAVs), and the radioactive environment of the reactor contributed to both the initial failures and the eventual successes of the recovery efforts. The initial emergency response to the wreckage, which was triggered by a 9.0 magnitude earthquake and subsequent tsunami, was widely criticized by the public for poor communication, lack of preparedness, and delayed decision-making. Through an ANT framework, the analysis challenges the conventional narrative that singularly blames TEPCO, instead revealing an interdependent network where government intervention, technological innovation, and environmental constraints shaped the trajectory of crisis management. UAVs in particular emerged as critical non-human actors, enabling remote assessments of hazardous reactor conditions, though they required significant technological adaptations to function effectively under extreme radiation. By analyzing secondary sources, technical reports, and governmental policy documents, it is evident that the alignment of interests among actors, policy reforms, and technical innovations ultimately led to a more coordinated and resilient response. Establishing all actors as essential components within disaster management networks contributes to a deeper understanding of policy development, engineering practices, and crisis planning in high-risk environments.

By working on the both the technical project and the STS research, I now have a more comprehensive understanding of the development and deployment of teleoperated systems. Developing Dexterity allowed me to experience the practical challenges of designing an intuitive, real-time teleoperated system. This hands-on experience helped me better understand the role of remote technologies in hazardous, high-stakes environments, which was useful going into my research on the Fukushima crisis response. The technical knowledge I gained through building Dexterity allowed me to analyze the limitations, design trade-offs, and necessary innovations of teleoperated systems operating in extreme conditions. Insights from the Fukushima case study, particularly the need for robustness, adaptability, and user trust in extreme environments, allowed me to reflect on my technical design and its place in a hazardous laboratory setting. While the focus of my technical project was intended for controlled hazardous settings, the STS research expanded my view to consider the greater societal and environmental impacts of teleoperated robotics in a large-scale disaster, ultimately connecting my technical work to its broader significance.