Thesis Project Portfolio

Project Dexterity

(Technical Report)

Analysis of Teleoperated Robots at Chernobyl

(STS Research Paper)

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Sociotechnical Synthesis

Project Dexterity presents an integrated haptic control system enabling safe, dexterous manipulation of hazardous materials via a wearable glove and a remotely operated humanoid robotic arm. The goal was to design an affordable yet precise manipulation tool by using open source designs and accessible components to broaden applicability for smaller research labs and educational institutions.

The system features a control glove embedded with Hall effect sensors with rotating magnets and inertial measurement units to accurately track finger and wrist movements. These movements are wirelessly transmitted to a robotic arm through a peer to peer WIFI connection. This humanoid arm is modeled after the open-source Dexhand project. The robotic hand comprises nineteen degrees of freedom, including precise finger articulation and wrist orientation. Finger movements are driven by PWM controlled servos, while wrist orientation utilizes FeeTech serial servos.

Pressure sensors on each robotic fingertip provide real-time tactile feedback transmitted wirelessly back to linear resonant actuators embedded in the glove's fingertips. This tactile feedback mirrors the pressure experienced by the robotic arm, enhancing user interaction realism and control precision. The system is controlled by ESP32 microcontrollers. Embedded software written in C++ using the Arduino framework manages real-time data transmission, sensor readings, servo control, and haptic responses. This project delivers a cost effective alternative to commercial haptic teleoperation systems, making advanced hazardous-materials handling accessible to smaller research labs and educational settings.

Analysis of Teleoperated Robots at Chernobyl examines the failures of teleoperated robots deployed during the Chernobyl nuclear disaster cleanup, emphasizing how technological shortcomings were significantly influenced by sociotechnical factors. Following the catastrophic reactor explosion in 1986, Soviet authorities attempted to use teleoperated robotic systems to manage hazardous radioactive materials and minimize human exposure. However, these early robotic solutions rapidly succumbed to the intense radiation, terrain challenges, and design mismatches, severely limiting their effectiveness and forcing reliance on human "liquidators" to clean up the rest of the radioactive waste.

Utilizing Actor Network Theory as a conceptual framework, this research examines the interactions between human operators, technical systems, and institutional structures involved in the cleanup efforts. Through archival research, technical documentation reviews, and expert interviews, it becomes clear that the robot failures were not merely technical but deeply embedded in broader sociotechnical dynamics. Key factors included inadequate operator training, ineffective communication protocols, bureaucratic inefficiencies, and geopolitical tensions restricting international technology sharing.

The analysis reveals breakdowns in translating environmental conditions into robotic design requirements, highlighting how institutional secrecy and misaligned expectations compounded technical deficiencies. The study concludes that future disaster response technologies must address both technical robustness and the surrounding sociotechnical network, advocating for improved training, transparent communication, and integrated institutional support. By recognizing these interconnected factors, policymakers and engineers can better develop resilient robotic systems, enhancing effectiveness and safety in high risk scenarios.

Project Dexterity and Analysis of Teleoperated Robots at Chernobyl are closely intertwined, as both explore using robots within hazardous environments. The Dexterity project develops a robotic armature system explicitly designed to safely handle hazardous materials through intuitive, real time human control and tactile feedback. This approach directly addresses key technical failures observed at Chernobyl, such as inadequate robotic robustness, limited operational reliability, and insufficient feedback mechanisms for remote operators. Dexterity aims to overcome these shortcomings by using accurate sensors, wireless communication protocols, and user oriented design, making it more effective and reliable in dangerous situations.

Moreover, the sociotechnical analysis emphasizes that technology alone is insufficient without proper attention to the human and institutional components within the network. It highlights the importance of thorough operator training, clear communication protocols, and effective institutional oversight, factors that contributed significantly to failures at Chernobyl. Recognizing these insights, the Dexterity project explicitly integrates ergonomic considerations, tactile feedback, and responsive wireless control. By acknowledging and addressing both the technical and sociotechnical dimensions, Dexterity learns from this historical event to ensure its technical operation is effective to the end user. Together, these projects illustrate the necessity of considering human factors in future technological advancements to achieve successful and safe operations in hazardous environments.