Sociotechnical Synthesis

Dexterity: A Low-cost, Remotely Controlled, Humanoid Robotic Arm

(Technical Report)

To Higher Ed. And Back Again: Increasing Access to Higher Education for the Rural United States

(STS Research Paper)

An Undergraduate Thesis Portfolio

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Both of my projects address significant, yet distinct, challenges within the engineering and societal domains. On the technical side, my capstone project focused on developing an affordable, haptic finger-tracking glove that controls a robotic hand designed for the safe manipulation of hazardous materials. This innovation is important because it minimizes human exposure to dangerous substances while providing a cost-effective alternative to expensive and bulky existing systems. My socio-technical study investigated the stark disparity in college enrollment rates between rural and urban communities. Addressing this disparity matters because the lack of educational access in rural areas reinforces cycles of poverty and limits economic mobility. Each project stands on its own, reflecting a broader commitment to using innovative approaches to improve quality of life through enhanced safety and increased opportunities.

The primary challenge of the capstone project was to design and implement a control system capable of translating precise human finger movements into movements of an open-source humanoid robotic arm. A haptic glove system was developed that incorporates hall-effect sensors, inertial measurement units, and pressure sensors, all working together to control a robotic hand in real time. The glove provided vibrational feedback that mimicked the sensation of touch during object manipulation. Extensive testing demonstrated that the system reliably achieved rapid response times with delays on the order of several milliseconds and maintained accurate movement tracking. However, challenges were encountered, such as the unimplemented 3 degree-of-freedom (3DOF) elbow movement and the inability to incorporate resistive haptic feedback due to hardware constraints. Despite these limitations, the experimental evidence validated the design approach and showcased significant potential for a safer, more accessible method for handling hazardous materials in laboratory settings.

The socio-technical investigation focused on understanding the systemic barriers that lead to lower college enrollment rates for rural students. Utilizing a post-positivist framework, the study examined quantitative data such as enrollment figures, graduation rates, and financial aid distributions alongside qualitative insights gathered from interviews and case studies in rural communities. The analysis identified critical factors impeding educational access: financial constraints, limited guidance for navigating college pathways, teacher shortages, and a lack of robust college-preparatory resources. Additionally, the research highlighted emerging challenges for minority and ESL students in these contexts as rates of these students in rural areas continue to increase. The findings underscore the need for targeted interventions, such as enhanced digital connectivity, localized scholarship programs, and systemic improvements in educational infrastructure, to address these multifaceted barriers effectively.

The work on the haptic glove–robotic hand system successfully demonstrated that advanced sensor integration and responsive control mechanisms can be engineered to safely manipulate hazardous materials. The prototype's rapid response time and precise movement control validate the design approach undertaken by the project team, despite current limitations such as the unimplemented 3DOF elbow movement and incomplete resistive haptic feedback mechanism. Future work should focus on addressing these hardware challenges by incorporating more robust components and further refining the control algorithms. Additional research could also explore the integration of adaptive feedback systems to enhance the device’s functionality under an even broader range of hazardous conditions.

My socio-technical study has provided valuable insights into the underlying factors that hinder access to higher education for rural students. Through the analysis of comprehensive data sets and qualitative evidence, my research identified several critical barriers including financial constraints, limited familial guidance, and insufficient preparatory resources. Future investigations should build on these recommendations by implementing and evaluating targeted interventions such as digital platforms for educational support and enhanced community partnership models. Studies examining the long-term outcomes of these interventions on rural enrollment rates and academic performance will be essential. Further exploration of emerging technologies such as AI-driven educational support systems and their potential impact on policy reform at various government levels is a new area of improving educational access that should be considered.

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