Research Vision Senuri Rupasinghe

My ultimate goal in research is to apply the laws of quantum mechanics to the development of technologies and robotics at the nanoscale. This means more than just exploring exotic physics-- it means figuring out how to harness quantum behavior to design, build, and control devices that operate at the scale of individual atoms or molecules. At the heart of this goal are three deeply connected questions: First, how do we achieve precise control over quantum systems at the nanoscale, especially when they're constantly being disrupted by noise, disorder, or thermal effects? Second, how do we actually engineer devices-- quantum dots, molecular junctions, nanoscale sensors-- where quantum effects don't just exist, but serve a real purpose? And third, how can quantum subsystems be integrated with classical control mechanisms, as they would need to be in a functional nanorobot or hybrid platform?

To start making progress on these questions, I built an interactive simulation tool for quantum transport. The project began as a way to visualize conductance through a lattice using the tight-binding model and Landauer formalism. But as I dug deeper, it became clear that this was also a practical environment for exploring much broader questions: how electron wavefunctions behave in disordered systems, how magnetic fields shape current pathways, and what happens when you inject a quantum state into a system with nontrivial geometry. With this framework, I've been able to design nanoscale structures and analyze how quantum interference, boundary effects, and coherence loss all play into the dynamics of transport.

This work has helped me build the kind of intuition that's essential for nanoscale quantum engineering. For example, I've observed first-hand how sensitive transmission is to even slight disorder, and how coherence can be completely suppressed depending on system parameters. I've explored edge state formation under magnetic fields, and how this behavior changes across regimes. In doing so, I've found myself asking: What breaks coherence, and what preserves it? What designs are robust to noise? These are the same challenges that would show up in trying to build functional quantum devices-- not in the abstract, but in the actual materials and fabrication constraints we face today.

I'm especially interested in how this kind of modeling can contribute to the larger problem of building hybrid systems-- ones that combine quantum behavior (like coherent sensors or transport channels) with classical control, actuation, or feedback. In the context of nanorobotics, that means working toward a future where quantum-enhanced modules are just one part of an integrated nanosystem. For that to happen, we need tools that can simulate, predict, and help design quantum behavior in structured environments. That's what my quantum transport simulator has started to become for me: a testing ground where I can explore what's possible when quantum mechanics meets design.

That said, I see this tool as a foundation-- not a destination. The simulator will continue to evolve, and I plan to extend it with support for dynamic potentials, decoherence modeling, and richer device architectures. But more importantly, I'm actively seeking out research and career opportunities that will allow me to grow beyond what I can build on my own. I want to work with others who are asking big questions about quantum systems, device engineering, and nano-integration-- whether in research groups, industry labs, or interdisciplinary collaborations. I see this as a long-term commitment, and I'm excited to keep developing both my skills and my understanding of what's needed to bring quantum nanotechnology and nanorobotics closer to reality.