Statement of Purpose

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Contents

1 M.S. in Robotics – MSR

Instead of a human search and rescue team, imagine Atlas (the biped robot) penetrating a disaster site to extract trapped families. This is just one of the many hazardous jobs performed by humans. My ambition is to lead industrial R&D towards robotics solutions that minimize human involvement in such jobs. Through my life's work, I want to advance robotics capabilities in similar unstructured environments with primarily three focuses: legged locomotion, task & motion planning, and optimization.

My motivation to pursue robotics originated while interacting with a quadruped in Hiroshima University's Cybernetics lab in summer 2019. I was fascinated by the algorithms that took in a complex robotic system and brought out a useful motion, which we humans recognize as walking. Fueled by this passion, I founded an institute-funded quadruped team tackling the RoboCup Rescue League competition. The goal is to autonomously explore the life-size disaster site to locate the maximum number of victims. With our understanding of impedance control and contact schedule optimization, we implemented a modified Bézier curve gait and watched our simulated robot climb steep inclines.

As I learned more about legged robots, I saw that **legged locomotion** was not limited to a single problem — there was a glaring need for multi-modality. In fact, the DARPA SubT Challenge in September 2021 demonstrated that multi-modality is essential for resilience in robotics. We require advancements across perception, planning, and controls to produce autonomous locomotion capable of exploring unstructured disaster terrains. These include finding gait patterns, more energy-efficient than wheeled locomotion, and sensing algorithms that infer foothold constraints in real-time. But what if the sensing fails? Then could generalized controls overcome complex foothold constraints like steep stairs, slippery terrain, and sharp rocks? With further advancements, I envision bipeds like Atlas relying on reflexes to brace against impact by extending their arms. Could they prevent the fall altogether by reflexively gripping a rigid object? My pursuit of such resilience in legged robots aligns with the vision of the **Robomechanics Lab** under Prof. Aaron Johnson — to study robots not under lab conditions but in challenging real-world environments. Furthermore, I believe that the understanding gained from *"Biomechanics & Motor Control"* by Prof. Hartmut Geyer and *"Underactuated Robotics"* by Prof. Matt Travers will prepare me for research in the Robomechanics Lab.

My final-year thesis under [redacted], *"Mapping Regions of Dynamic Activity and Building Dynamic-free 3D Occupancy Maps,"* touched upon my second area of interest: **task planning**. My interest spans two types of problems: (1) Non-exploratory, well-defined tasks, like filling a cup from a tap after fetching it from a shelf across the kitchen (2) Exploratory, abstract tasks, like searching for lost keys inside a house. In the latter problem, the mobile robot may have to open a drawer, search underneath a heap of clothes, twist the doorknob to search another room, and so on. Instead of passively understanding the environment, the robot "actively" interacts to learn more. Now replace lost keys with trapped humans. The problem area remains the same, but suddenly, the applications are significantly more profound. Through *"Planning and Decision-making in Robotics"* by Prof. Maxim Likhachev, I am keen to understand decision-making algorithms that can solve such task planning problems.

I enjoy **optimization**, my third area of interest, as an applied mathematics problem and its utility in trajectory, pose-graph, and policy optimizations. Having studied this topic closely in courses, I implemented it in competitions, like F1/10th, and projects, like *"Multi-robot Capture of a Non-adversarial Target using MILP."* From topological optimization of nuclear warheads to minimizing corporate expenses, the ubiquity of optimization drives my passion for this topic. I want to work towards breakthroughs in this field that remove computational bottlenecks from real-time decision-making.

Realizing that my ambitions required advanced robotics skills, I purposefully worked on expanding them in my final year. My proudest fourth-year project is the two-wheeled self-balancing bot. The challenge was not technical but due to the limitations posed by the COVID-19 lockdown. I didn't have access to laser cutting or 3D machining. Constrained in mechanical parts, I used a phone box as the bot's chassis and other home-available equipment. Watching the bot stabilize despite being nudged made me confident in my ability to work with limited resources.

My efforts have continued in my ongoing research project under [redacted]. Our hypothesis is that the number of equilibrium configurations of a flexible inverted pendulum varies with the base angle. During this project, I learned formal research methodology, i.e., hypothesis proposal, mathematical backing, experimentation, observation data analysis, and preliminary conclusions. My first round of experiments was not in line with the simulations. Undeterred by this failure, I redid the analysis, identified corrections, and conducted another round of experiments. The new observations proved our initial hypothesis, and we are now preparing our results for publication. This experience has prepared me for the iterative nature of research.

Working on these research projects has evolved my organizational skills. Leading and establishing the 15-member quadruped team took me through a steep learning curve in project management, like proposing the budget to a panel of professors and conducting recruitments. Besides this, as the Electronics & Robotics Club convener, I learned about teamwork while organizing competitions with a footfall of over 600 students. In our flagship competition, XLR8, I guided participants and debugged their circuits while being surrounded by numerous first-year students excitedly working on their first remote-controlled wheeled robot. While facilitating their growth into robotics has been a gratifying experience, conducting an event of this scale also taught me what a team could achieve. My experiences made me much confident about working in large, multi-part R&D teams in the future, motivated to build disaster relief robots.

The M.S. in Robotics at CMU also provides a platform for applied research, beyond coursework, at the union of my interests — the **Robomechanics Lab** under Prof. Aaron Johnson (interaction between robot and environment primarily related to contact planning) and the **Robotic Exploration Lab** under Prof. Zac Manchester (papers related to fast trajectory optimization).

My love for robotics has led me to pursue these interests alongside my current job in finance. Identifying deeply with your core value, *"My heart is in my work,"* I believe that CMU is where I can push towards making my passion my work. Furthermore, I am confident that researching under distinguished professors – **Prof. Johnson** and **Prof. Manchester** – will be instrumental in realizing my ambitions for disaster relief robots.

Sincerely yours,
Siddharth Saha
Mumbai, December 4, 2021

2 M.S. in Robotic Systems Development – MRSD

Instead of a human search and rescue team, imagine Atlas (the biped robot) penetrating a disaster site to extract trapped families. This is just one of the many hazardous jobs performed by humans. My ambition is to lead industrial R&D towards robotics solutions that minimize human involvement in such jobs. Through my life's work, I want to advance robotics capabilities in similar unstructured environments with primarily three focuses: legged locomotion, task & motion planning, and optimization.

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Working on these research projects has evolved my organizational skills. Leading and establishing the 15-member quadruped team took me through a steep learning curve in project management, like proposing the budget to a panel of professors and conducting recruitments. My experience at Goldman Sachs has expanded these skills further and allows me to offer a unique insight into financial systems, like budget optimization and quantifying returns — essential considerations in product development. Besides this, as the Electronics & Robotics Club convener, I learned about teamwork while organizing competitions with a footfall of over 600 students. In our flagship competition, XLR8, I guided participants and debugged their circuits while being surrounded by numerous first-year students excitedly working on their first remote-controlled wheeled robot. While facilitating their growth into robotics has been a gratifying experience, conducting an event of this scale also taught me what a team could achieve. My experiences made me much confident about working in large, multi-part R&D teams in the future, motivated to build disaster relief robots.

In the MRSD curriculum, the **capstone project** provides a platform to find industrial applications for the research outcomes at CMU — the Robomechanics Lab (interaction between robot and environment primarily related to contact planning) and the Robotic Exploration Lab (papers related to fast trajectory optimization). Peer learning and collaborative effort are imperative in any sustainable business model, and the capstone would let me practice this in a robotics context. The program's unique management component and industry-affiliated internship opportunity are exciting as they would teach me to match the cadence of decision-making to the pace of innovation.

My love for robotics has led me to pursue these interests alongside my current job in finance. Identifying deeply with your core value, *"My heart is in my work,"* I believe that CMU is where I can push towards making my passion my work. Furthermore, I am confident that collaborating with a diverse and distinguished cohort will be instrumental to my success in leading projects in the robotics R&D industry and realizing my ambitions for disaster relief robots.

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Siddharth Saha
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