Statement of Purpose for M.S. in Computer Science at Berkeley

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The amorphous character is an enigma that commonly appears in science fiction and fantasy media. They can be relatable, like the friendly but clumsy sentient blob named Bob from "Monsters vs Aliens" (2009 film). Sometimes they seem unstoppable, like the liquifying robot T-1000 whose sole purpose is to destroy our protagonists from "Terminator 2: Judgment Day" (1992 film). Always, they make creative use of their non-fixed form, such as the blobs that can merge and split to solve physics-based puzzles in the beloved franchise "LocoRoco" (2006 video game). Perhaps the reason the amorphous character keeps coming back in entertainment media is because we enjoy witnessing their creative problem solving potential. The amorphous character can morph into whatever they want, limited only by their imagination.

My goal through earning a PhD in computer science is to become a top expert in controlling and simulating physics-based characters. My main focus will be on amorphous characters, which when successfully trained will be capable of completing complex tasks by making intelligent use of their non-fixed form. This type of character is not limited to amorphous blob creatures, but also modular reconfigurable robot systems, which would be the real world constructable equivalent of an amorphous creature. My strong foundation in physical simulation and optimization combined with my newfound interest in reinforcement learning, artificial intelligence, and digital evolution puts me in the perfect position to tackle this field.

In my final year of Engineering Science at UofT, I completed an undergraduate thesis with Professor David Levin at the Dynamic Graphics Project (DGP) lab on amorphous character control. This was done using back propagation through time on a differentiable material point method (MPM) simulator to optimize a control sequence for a topologically morphing blob given an initial and target shape. The simulation method of choice, MPM, was chosen for its natural ability to handle topological change due to being a particle method as opposed to a mesh-based method. I derived an MPM specific control parameter through deformation gradients, which can be considered as the meshless equivalent to rest-state parameterization, a method previously used for mesh-based elastic character control. I presented my work at MOTOGRAPH 2019, a Montreal/Toronto/Waterloo pre-SIGGRAPH conference, with some very pleasing animations of shapes morphing their topologies through internal forces. This research experience has greatly prepared me for the next task of training generalized amorphous character controllers through reinforcement learning.

After my undergraduate degree, I joined Rocscience Inc as a software developer of physics engines. My main responsibility is leading the development of the physics engine for RocFall3, a new software for large scale 3D rockfall trajectory computation. RocFall3 is used to assess the safety of slopes at risk of rockfall near civilian areas and infrastructure. To build RocFall3, I reviewed literature as far back as the 1990s up to the present day on rigid body simulation of mesh-based geometries. In addition, I dealt with many challenges unique to rockfall simulation such as large multi-material irregular terrain, tumbling rocks with high angular velocity, and extra importance placed on energy conservation. Through this project, I learned how to design a large codebase for maintainability, modularity, and usability. Moreover, I gained experience communicating the knowledge I gathered to other employees in the company through technical documents and presentations. Other experiences I gained include managing intern projects and working in a multidisciplinary team. Overall, building RocFall3's physics engine allowed me to gain invaluable research and team experience, but also a perspective on using simulation to predict real phenomena as opposed to realizing fictional phenomena.

I want to continue researching simulation methods for amorphous creatures made up of a variety of materials. An interesting direction would be co-dimensional creatures, made up of connections of rods, sheets, and solid volumes. This creature would have endless possibilities of tearing, crumpling, and morphing to accomplish different tasks. I believe Professor James F. O'Brien would make a great advisor to this project due to his vast experience with tearing, cracking, deformation, and fracture simulation over his career.

My end goal is to design a simulator for amorphous creatures and then apply deep reinforcement learning to learn their controllers. Amorphous creatures naturally have much larger action spaces than rigid characters, which leads to an interesting challenge to be tackled. I am also interested in designing a simulator for the real world equivalent of amorphous creatures, which are modular reconfigurable robot systems. I would train the robotic controllers in the simulation environment, then construct the physical robots to deploy the controllers to. The goal of these robots is to accomplish swarm tasks in the real world such as gathering materials or combining into different shapes. I believe Professor Pieter Abbeel and Professor Sergey Levine would make great advisors for these projects due to their pioneering contributions to deep reinforcement learning, their applications of deep reinforcement learning to robotics, and their mission of creating public educational content for deep reinforcement learning.

I am truly passionate about bringing amorphous characters to life. My research and professional experience at UofT's Dynamic Graphics Project lab and Rocscience Inc have given me a strong foundation and confidence in my vision. I hope to continue my research journey with the inspiring community at Berkeley's computer science department, and make important contributions to computer graphics, simulation, and artificial intelligence.