Statement of Purpose for SFU M.Sc. in Computing Science

Michael Xu
Webpage: michaelx.io

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 graduate degree in computing 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 applying amorphous character control to simulate imaginative virtual characters. One project idea is to train a virtual slime via reinforcement learning to complete complex locomotion objectives around obstacles by utilizing its non-fixed form. Another idea would be to conduct simulation experiments on a wide variety of algorithms for simulating and training virtual amorphous and/or deformable characters. Professor Xue Bin Peng would be a great advisor for these projects due to his valuable experience and recent strides in reinforcement learning for character animation. Professor KangKang Yin would also be a great advisor because of her long history of research in character animation, simulation, control, and notably her experience with soft-body characters.

There are currently no reliable tools for quantitatively describing the topology of point clouds simulated via physically based particle methods such as MPM. Despite this, the amount of researchers applying particle methods to topology optimization and amorphous character control is only growing. To help facilitate these researchers, I plan to develop new methods and benchmarks for quantitatively measuring this missing topology information. I also plan to use these methods to reliably convert arbitrary frames of solid simulation via particle methods to mesh-based methods such as the finite element method. Professor Hao Zhang would be a great advisor for this project due to his long history of research in geometry processing, specifically shape analysis.

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 SFU's computing science department, and make important contributions to computer graphics, simulation, and artificial intelligence.