Understanding Motions of Silicon Robot Through Quality Diversity Algorithms

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Abstract

Simulation is now playing an important role in scientific fields, because we are not able to run physical tests for every assumption and every factor [1][2]. In order to find the movement capabilities of each robot, the Quality Diversity(QD) Algorithm is applied. After analyzing the data, we found that the Multi-dimensional Archive of Phenotypic Elites (MAP-Elites) algorithm, can help us build the repertoire of voxel based robots which can be used in future to solve assigned tasks.

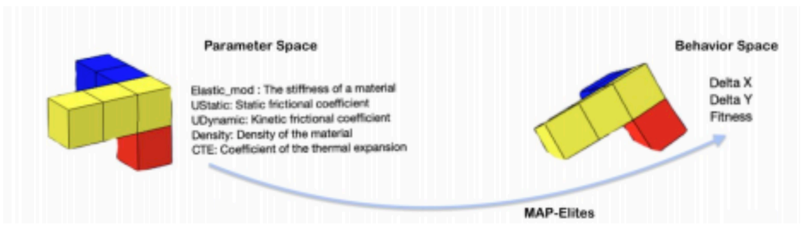

Figure 1. The robot on the left showed the original state and the robot on the right showed the ending gesture of the robot in VoxCraft-Viz. MAP-Elite would search in the 15 Dimensional space (3 materials and each material had 5 properties) to find the performance of each combination.

Introduction

Because of its flexibility and adaptability, soft robot is an excellent research tool to understand how to make robots more human-world friendly and even mimic the human body's working system. So, quantifying which soft robot designs, strategies, and behaviors could be faithfully simulated was not only for building better robots, but also for understanding the functional plasticity of biological systems during development and regeneration[1].

Instead of attempting to achieve a single task assigned by the scientists-like locomotion in one direction and find the best route, we cared about how diverse the robots behavior can be and how they conduct these behaviors. MAP-Elites algorithm was applied to illuminate search spaces, allowing researchers to understand how interesting attributes of solutions combine to affect performance, either positively or negatively [2].

Based on the set of high-performing, yet diverse solutions returned by MAP-Elites, we would be able to find the best solutions to a series of problems and further make the robot be able to solve different problems on its own.

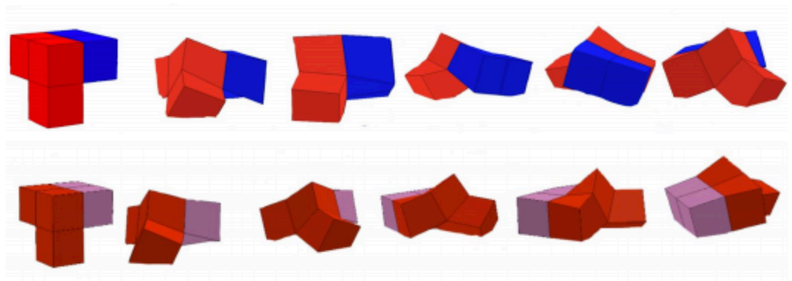

Figure 2. As the image showed, the same color would be the same material and the group of voxels that shared the same material would be that same. The first row of movement was generally a full clockwise rotation. The second rows behavior was more complicated, at first it was clockwise rotation, then it started vibration severely and did a half-circle anti-clockwise rotation.

MAP-Elites Algorithm

MAP-Elites algorithm would produce different materials to these robots by multiplying the parameters for the material properties. By doing this, each robot will be assigned with 15 parameters with unique behaviors. Then the behaviors would be stored in the descriptor-the displacement in x, y direction and the rotation angle. The descriptor is placed in the behavior space and linked with the parameter space. At the same time, there might be other parameters combinations that can lead to the same behavior, and MAP-Elites will determine which combination would be the elite solution.

VoxCraft

VoxCraft was a design software that allows researchers to test designs and discard bad ones before spending time and supplies to build them [2].

All the original robots were manually built in VoxCraft-Viz. The VoxCraft-Sim simulates voxels in parallel on a gpu. The simulations do not produce graphics, but a history file will be recorded that traces the behavior of each voxel within a simulation, and can be replayed in VoxCraft-Viz [2].

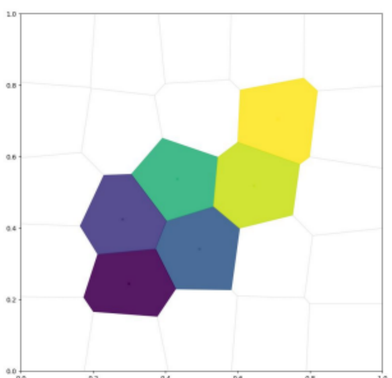

Figure 3. This is the Voronoi plot for the MAP-Elites result. The lighter color indicated the higher fitness value, which is the distance from the origin (0,0) [3].

Procedures

- After deicing the morphology of the robots, VoxCraft-Viz can be used to visualize it and it can be exported in a special file format that can be run in the simulator.
- In the simulator, VoxCraft-Sim, we can define which parameter will be used for current experiment. There's also sections to set up the experimental environment, such as temperatures and gravity.
- MAP-Elites is used to be the controller of the material properties-elastic_mod, uStatic, uDynamic, density, coefficient of thermal expansion-by multiplying the original values. By placing all the behavior data into a Voronoi map, which will be divided into different regions, MAP-Elites matches descriptors to the closest centroid of a certain region [3]. If there are more descriptors falling into the same region, MAP-Elites will elite the one that has the highest fitness value-in this case, fitness is the distance from the origin.
- After running the simulations, experiments data will be saved in different formats. History files can be replayed in VoxCraft-Viz and visualize the behavior of the robot and other files can be used to analyse experiment performances and file the elite parameters.

Future Work

The results illustrated the diversity of behaviors, however a lot of questions remain are waiting to be answered. We are seeking for morphologies and environment that can produce stable results and different parameter combinations.

Acknowledgments

Sincerely thanks Union College Davenport Research Fellowship and Computer Sciences Department for funding and supporting this project.

References

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