BIO-INSPIRED ROBOTIC NAVIGATION ON VARIED TERRAIN

Computer Science and Artificial Intelligence BSc
Final Year Project

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INTRODUCTION

In this project, I have investigated autonomous robotic navigation through localized decisions based on previous experience. Self-preservation is key in biological and computational agents for survival. For example, if the Mars rover gets stuck, there is no one to fix it. An autonomous robot will need to know its own limitations and avoid potentially hazardous environments.

SIMULATION

A simulation environment was generated using Perlin noise. This made a 3D world of different terrains, stored within a 2D array. The agent was deployed using evolutionary strategies to evolve a neural network. The input to the prediction model was a stereo vision disparity map. Several architectures were trialled such as 1D, 2D convolutions and linear neural networks.

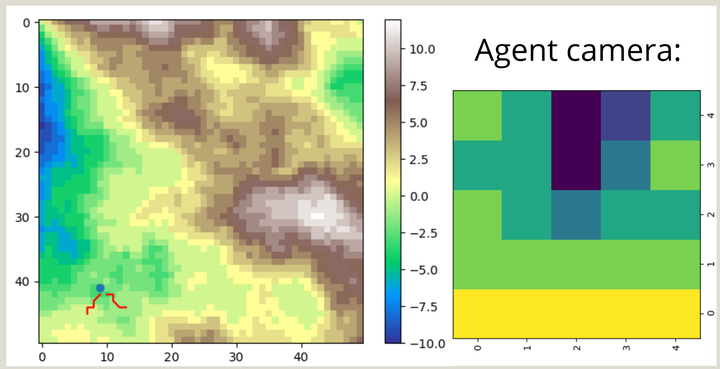


Figure 1: Visual field denoted by red lines. The disparity map is generated.

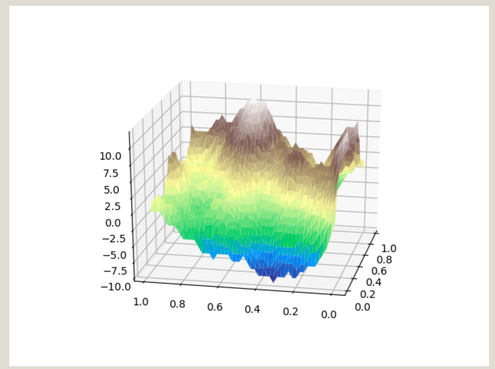


Figure 2: Simulation terrain represented as 3D.

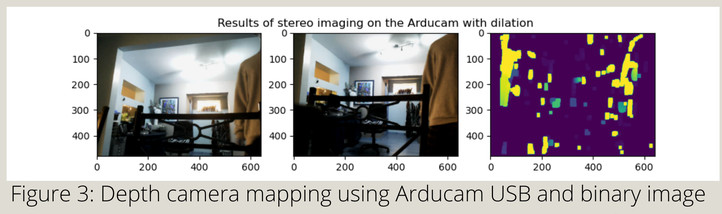


Figure 3: Depth camera mapping using Arducam USB and binary image conversion. Dilation is applied to this image to help highlight features.

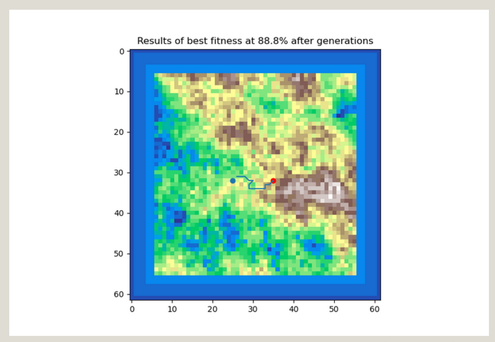


Figure 4: Simulation using 2D convolutional neural network. This evolved to use contours.

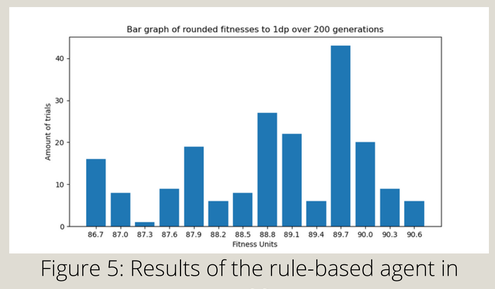


Figure 5: Results of the rule-based agent in terms of fitness.

THE WHEG

The Wheg is a mix between a wheel and a leg.

Whegs combine the positive attributes of wheeled and leg driven methods of locomotion keeping the cyclic efficiency of a wheel. Robot legs have high energy consumption, but wheels are limited on advanced terrain.

The Whegs used were 3D designed and printed making them low cost and custom for the chassis.

BIOLOGY

The Wheg chassis was inspired by cockroach locomotion over terrain. Blattodea are rapid runners and use their limbs within synergetic movements to climb over terrain.

Whegs use this concept where it keeps 'running' at an obstacle. The cockroach bends its back to distribute weight to improve climbing over terrain. This concept was applied to the robot chassis.

PHYSICAL ROBOT

The chassis made use of servo rotation in the back to redistribute weight over terrain.
The controller was a Raspberry Pi Zero with stereo vision camera input.

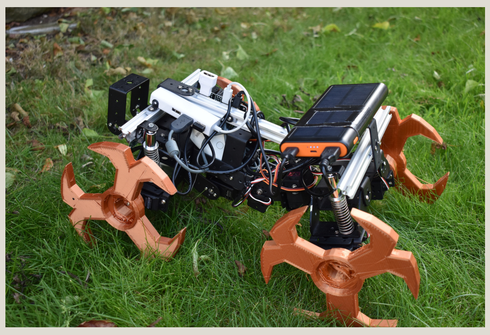
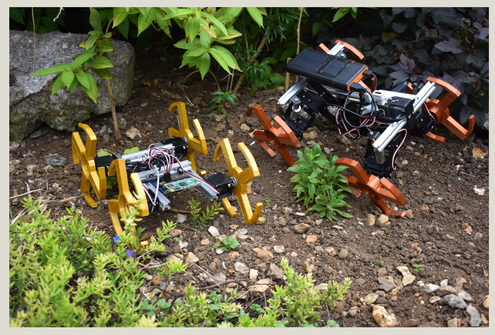


Figure 6 (left): Wheg v3 robot with back bending and tri-pointed whegs.

Figure 7 (right): Wheg version 1 and 2 improved the back on v2.



RESULTS AND ANALYSIS

The genetic approaches showed that 2D convolutional networks performed best out of the given network architectures. The best algorithm was the group algorithm which allowed more diversity to arise in the population.

A rule-based solution worked to slightly higher accuracy and ended up being more trustworthy with danger.

Back bending improved climb as seen in the figure to the right.

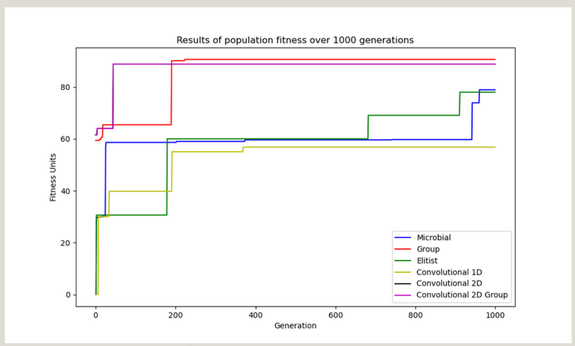


Figure 8: Results of all genetic algorithms approaches and convolutional neural networks.

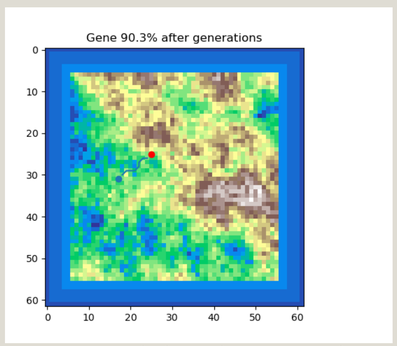


Figure 9: Rule-based agent avoiding danger (water)

Figure 10: Wheg robot bending its back to climb over terrain.

CONCLUSION

The use of back bending allowed the robot to navigate over terrain that a non-back bending robot could not.
The simulation showed that robots can exploit visual information and learn to avoid danger.

Rule-based approaches offer more trustworthy agents which would be more applicable to expensive Mars rovers.

RELATED LITERATURE

Comparing cock-roach and whegs robot body motions. IEEE International Conference on Robotics and Automation, 2004

Interspecific evaluation of octopus escape behaviour.Journal of Applied Animal Welfare Science

Rough terrain intelligent robots through reinforcement learning, 2020