Complex Systems Project Proposal

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Goals and Aims of the Project

The goal of this project is to emulate the naturally emergent behavior of a penguin colony using swarm-based coordination. Our first aim is to design a set of behavioral rules for the individual penguins which result in emergent behavior similar to that of a natural penguin colony and maximizes survival. Our second aim, if time permits, is to evolve the rule set for the penguin colony to attain a similar emergent behavior as described in our first aim. We would like to do a thorough comparison of the rules defined in the first aim and those derived in the second aim.

Description of the Proposed Work

In this project, we introduce a user-defined colony of penguins into an environment to observe social thermal-regulation of the population. Common (or similar) rules for individual penguins and the environment (with spatial and temporal variations) are set up such that the collective behavior of the penguin colony resembles that in nature. The specific rules will be explored empirically or algorithmically to simulate the natural constraints. These constraints will include heat transfer between individual penguins in the population and between penguins and their ambient environment. Heat transfer will be determined by the neighborhood of penguins. An additional constraint will be a nominal temperature range that must be maintained by the individual penguins for survival; prolonged exposure of temperatures outside of this range will result in death of the individual. Our hypothesis is their huddling pattern is formed by the egoistic survival instinct from the penguin individuals, and that this behavior can be realized through evolutionary methods.

Motivation for the Project

Social thermal-regulation is an interesting animal behavior in social mammals, birds, and reptiles [1]. Understanding it helps to engineer energy-efficient solutions for us or artificial robots under extreme environments. Additionally, being able to evolve the behavior of the individual agents to achieve a complex collective behavior allows for more adaptive swarm robotic systems. We like penguins. Honestly, it's just that.

Metrics for Evaluating Success or Failure

The success of the first aim is determined by whether the predefined rules result in a collective behavior that is favorable to the survival of the penguin group. The success will be proportional to the percent of surviving population after a user-defined period of time, as well as evaluating metrics such as the average warmth of the colony. A more subjective measure of evaluating the success of the project is to analyze the degree of emulation of natural penguin colony behavior. We will document the behavior of the penguins by exporting a 2D frame for each discrete time step which will be culminated into a GIF. The success of the second aim will be determined by the ability to achieve the success of the first aim, with a specified degree of error, or better. Additionally, the success of the second aim will be determined by improvement in simplicity, fewer hyper-parameters, and computation time.

References

[1] Liz A. D. Campbell et al. "Social thermoregulation as a potential mechanism linking sociality and fitness: Barbary macaques with more social partners form larger huddles". en. In: *Scientific Reports* 8.1 (Apr. 2018), p. 6074. ISSN: 2045-2322. DOI: `10.1038/s41598-018-24373-4`. URL: `https://www.nature.com/articles/s41598-018-24373-4` (visited on 02/22/2021).