Emergent Penguin Swarm Behaviors

Final Project for EECE7065 Complex Systems

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Heat Exchange Model

Goal: Develop preliminary penguin agents and rules for movement. Implement heat exchange interactions among penguins and between penguins and the environment.

- Metabolic Heat Generation
  - $Q_{meta} = mc\Delta t_{meta}$
- Penguin-Penguin Heat Exchange
  - $Q_{21} = \frac{\kappa_1 \kappa_2 A_1 A_2 (t_2 - t_1)}{d^2}$
- Penguin-Environment Heat Exchange (Newton's Law of Cooling)
  - $Q_{env} = \kappa A(t_{amb} - t)$
- Temperature Change and Movement
  - $\Delta t_1 = \frac{\sum_{i=1}^{N} Q_{i1} + Q_{meta,1} + Q_{env,1}}{m_1 c_1}$
  - If temp $<$ lower bound, then move toward average location of penguins in neighborhood. If temp $>$ upper bound, then move away from average location.

Temperature Sensing Only Simulation

Goal: A simple test simulation on if temperature solely determines the emergent swarming behavior

- Heat transfer: penguins radiate heat into the environment with a linearly decaying temperature pattern
- Moving: if hot, go to cold area; if cold, go to hot area
- Penguins are "blind": they only sense temperature around them and decide on their movement

Conclusion: "blind" penguins will emergently swarm only with a strict range of hyper-parameters

Simulation Environment

Goal: create a framework to facilitate testing different movement strategies and model parameters

- Framework to manage overall flow of the simulation
    - Read parameters from a config file (allows batch processing)
    - Allow for different agent types modularly
- In each epoch:
    - Get movement decisions from each agent one at a time
    - Ignore any moves which cause collisions
    - Apply thermal model and update agents temperatures
    - Log metrics and save an image
- At the end of each simulation:
    - Save a GIF of the simulation
    - Display metrics such as survival and average temperature

Future Work

Goal: Integrate thermal model and penguin controls in discretized environment.

- Implement thermal model in new discretized environment with cell-cell interaction.
  - Each cell will have a heat transfer interaction with adjacent cells
  - Penguin cores will generate heat using metabolic heat generation
  - Different thermal conductivity for penguin interior, penguin exterior, and environment
  - Ambient air or environmental heat sink will remain
- Analyze the effects of hyper-parameters and agent controls.

Behavior Evolution

Goal: Explore evolution for generating rule policies for agents

Two possible approaches:

- Use evolution to explore parameters in our current model, keeping our rules the same
  - Easy with our current infrastructure
  - Decision models will be all the same
- Use evolution to create the rules and parameters
  - Use neural nodes with various functions like Sims [1]
  - Ability to generate interesting and novel decision models
  - May be difficult to implement — requires more infrastructure

References I

Karl Sims. "Evolving Virtual Creatures". In: *Proceedings of the 21st Annual Conference on Computer Graphics and Interactive Techniques*. SIGGRAPH '94. New York, NY, USA: Association for Computing Machinery, July 24, 1994, pp. 15–22. ISBN: 978-0-89791-667-7. DOI: 10.1145/192161.192167. URL: http://doi.org/10.1145/192161.192167 (visited on 04/09/2021).