Bachelor's Thesis
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Modeling Head-Bobbing in Pigeon Locomotion using Reinforcement Learning

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Abstract of Bachelor's Thesis of Academic Year 2022

Modeling Head-Bobbing in Pigeon Locomotion using Reinforcement Learning

Category: Science / Engineering

Summary

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Keywords:

Reinforcement Learning, Biomimetic, Pigeon, Locomotion

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0.1. Background: Reinforcement Learning

Reinforcement learning is a type of control system that attempts to execute tasks described by manually set cost functions by minimizing them using optimization algorithms or learning algorithms. In the case of deep reinforcement learning, the controller is modeled using deep neural networks and the cost function is minimized using gradient descent algorithms.

Reinforcement learning divides control systems into an agent and an environment. The agent acts the controller of the system that inspects its environment's state and sends output signals, or actions, that affect the environment. This mutual interactions creates a feedback loop between the two modules.

In the context of a pigeon tasked to move forward, the pigeon's brain and its nervous system connected to each limb act as the agent, and its surroundings, such as the ground and arbitrary objects on it, act as the environment. The environment outputs a state, such as the global position of the pigeon, which is used as the input for the agent. Using the provided state, the agent calculates and outputs an action, such as the torque of each joint in the pigeon's body. The action alters the state of the environment, and the environment outputs a new state and a reward. The reward describes how well the pigeon was able to execute its task, such as the current position of the pigeon relative to its previous timestep. The agent is updated to output sequences of actions that maximizes the cumulative reward, or return. The return can be interpreted as the inverted or negated cost function.

0.2. Preliminary Research

0.2.1 Modeling biological phenomena

0.2.2 Head-Bobbing in Pigeons

Frost and Davies' have proposed hypotheses regarding the functionalities of such behavior have been proposed [2] [1]. Both proposals highlight the use of the hold phase as a means to stabilize vision and the use of the thrust phase as a means to detect motion parallax and determine the distance between objects.

Frost's hypothesis links the functionality of the hold phase to the detection of backward motion within the eye [2]. Pigeons' heads, while flying or moving forward, would be detecting objects whose movements can be distinguished from the surrounding stationary objects. Since stationary objects would be moving backwards relative to the pigeons' eyes, desensitizing backward motion would be necessary for such distinctions to be detected. However, this desensitization would be detrimental to the pigeons' object recognition while the pigeons' heads are stationary. The hypothesis highlights the existence of "backward notch" cells which counteract the aforementioned desensitization. Such cells would be activated when the pigeons' vision is stabilized and allowing them to distinguish objects moving backward relative to stationary objects, hence the necessity of the hold phase during locomotion.

Davies' hypothesis challenges this notion and highlights the lack of necessary conditions to induce a hold phase by stating that "they would fail to detect objects moving backwards through the visual field at velocities similar to that of the bird, as their responses could not be discriminated from those caused by self-induced motion" [1]. Davies proposes the existence of cells that detect objects' movement relative to stationary backgrounds regardless of their directions.

In the context of our model, combining the two hypotheses leads to a mechanism that stabilizes the head of the pigeon relative to arbitrary stationary objects and activate cells that detect arbitrary motion during the hold phase.

Acknowledgements

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References

[1] DAVIES, M. N., and GREEN, P. R. Head-bobbing during walking, running and flying: relative motion perception in the pigeon. *Journal of Experimental Biology 138*, 1 (1988), 71–91.

[2] Frost, B. The optokinetic basis of head-bobbing in the pigeon. *Journal of Experimental Biology 74*, 1 (1978), 187–195.

Appendix

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