BERLIN UNIVERSITY ALLIANCE

COMBINING ARTIFICIAL NEURAL NETWORKS WITH AGENT-BASED MODELLING TO INVESTIGATE BUMBLEBEE EXPLORATORY FLIGHTS

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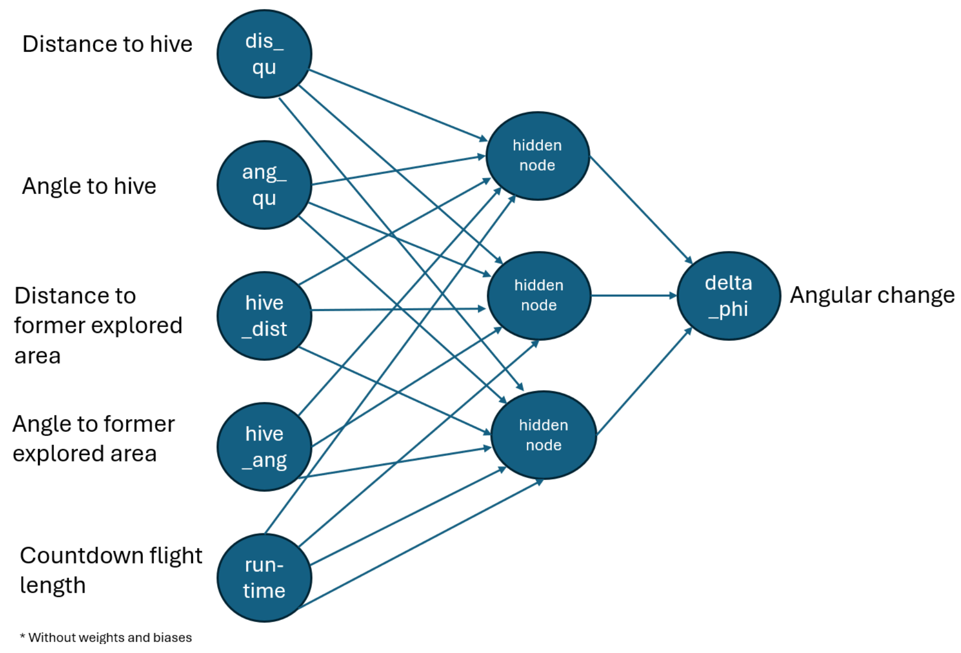
INTRODUCTION

Bumblebee foraging behaviour in *Bombus terrestris* involves exploration and exploitation flights, which are crucial for foraging success [1]. During exploration, bees execute looping flights around their nest to learn the locations of food sources. Recent advancements in harmonic radar technology have shown that these flights are influenced by prior experiences, rather than being random [2, 3].
As central place foragers, bumblebees begin and end their trips at the nest, resulting in distinct flight patterns. Exploratory flights exhibit curvy trajectories that enlarge with experience, while exploitation flights are direct routes to known food sources, maximising foraging efficiency. Our research aims to replicate these exploratory behaviours through agent-based models and artificial neural networks, focusing on the role of memory and the cognitive processes involved.

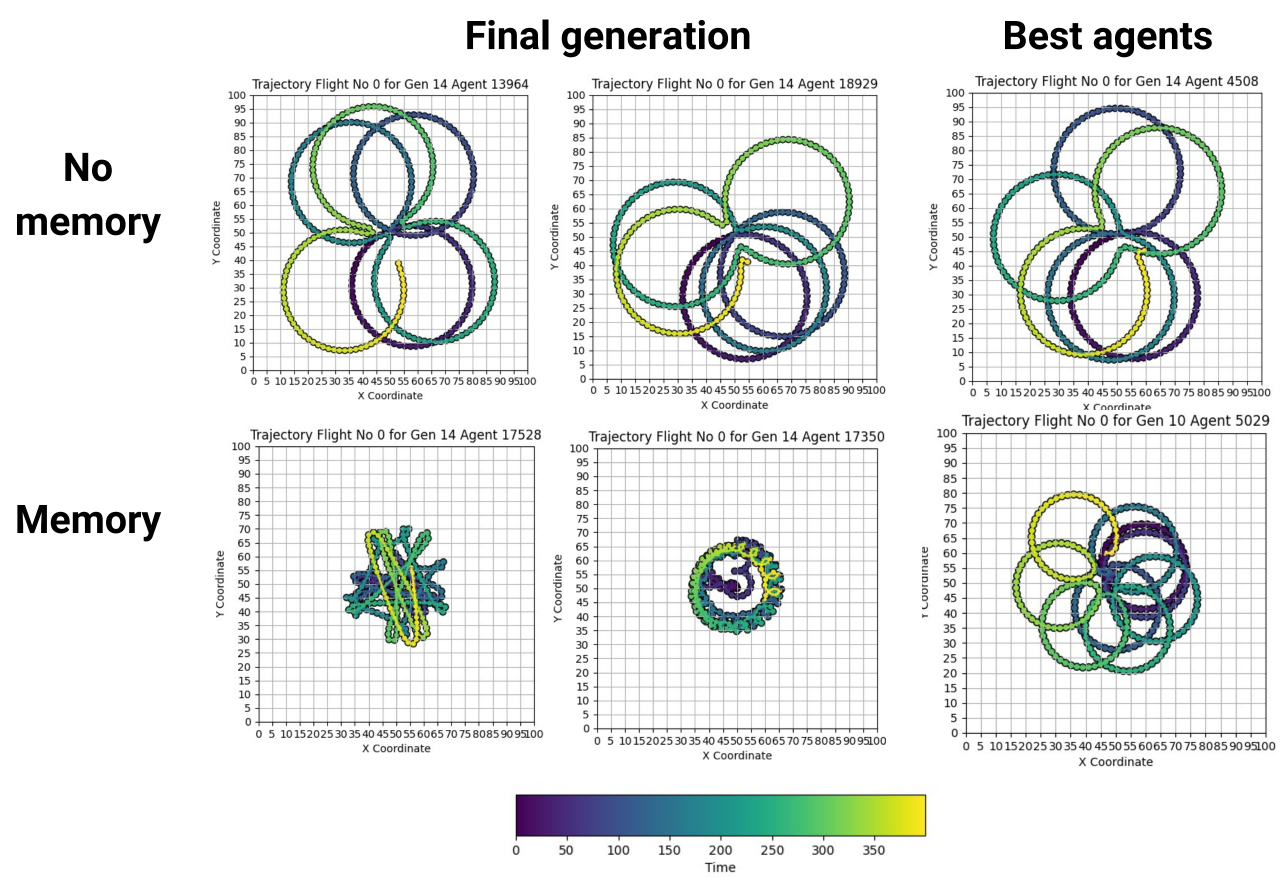
METHODS

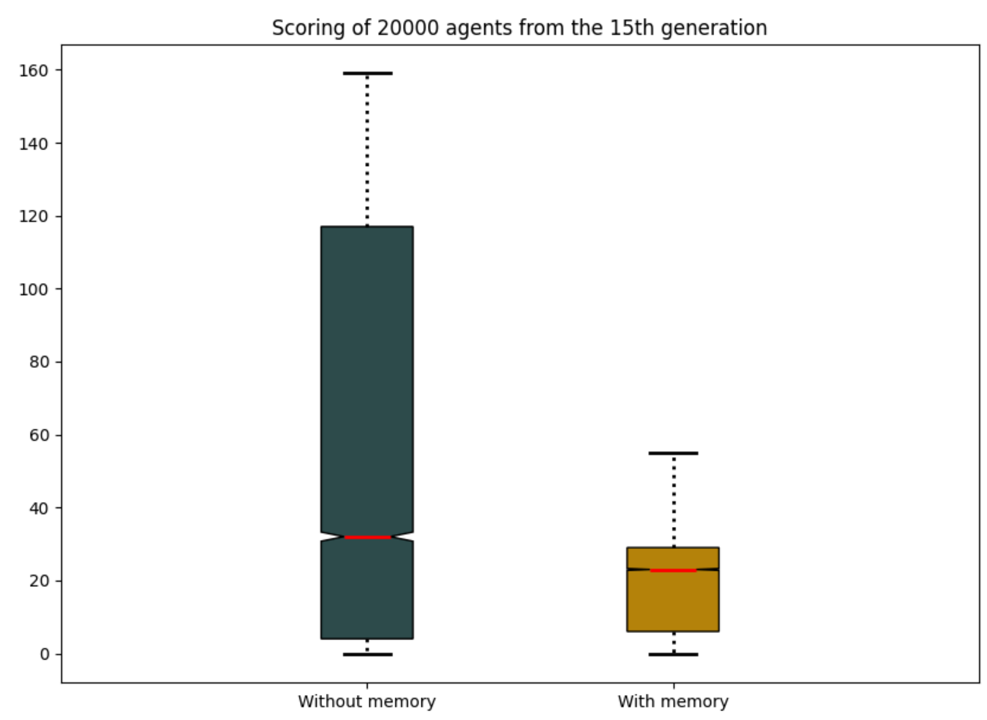


- Agent based simulation of 20 000 agents
- Agents have a neural network functioning as its cognitive system
- Simulated evolution across 15 generations
- Random mutations at each generation
- Selection based on two criteria: area explored and ability to return to the hive

RESULTS

The condition without memory showed significantly higher average exploration scores (*M* = 60.2, *SD* = 54.4) compared to the memory condition (*M* = 18.5, *SD* = 12.1). The range of scores was considerably broader in the no-memory condition, with scores ranging from 0 to 159, indicating increased variance in exploration behavior. In contrast, the memory condition exhibited a narrower distribution of scores, ranging from 0 to 55.





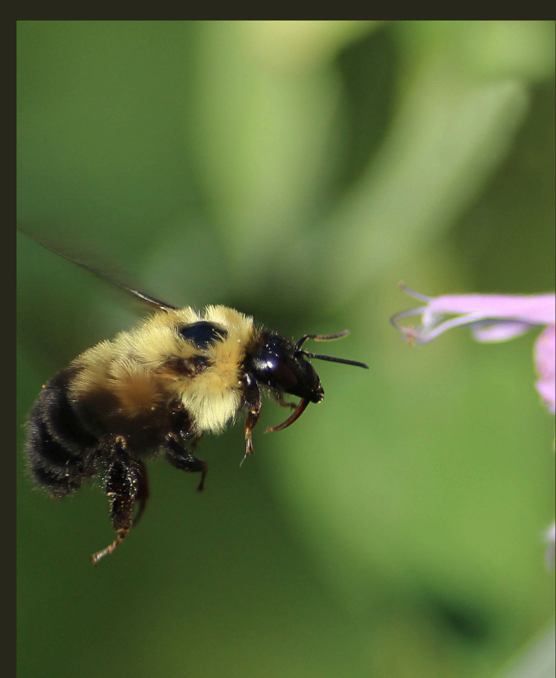
Statistical analysis revealed that the differences in exploration scores between the two conditions were highly significant, $t(21983)=105.78$, $p<.001$. The effect size, calculated as Cohen's d, was large (d=1.06), indicating a substantial difference between the two groups. The 95% confidence interval for the difference in means was [40.89, 42.44], further supporting the robustness of these results.

Thus, the simulation indicates that memory does not contribute significantly to an increase in the exploration area when the agents are required to return to the hive. Instead, agents without memory explore significantly larger areas, albeit with increased variability in performance compared to those with memory.

DISCUSSION

Our findings suggest that while memory may be critical for resource exploitation and returning to known locations, it may not be as beneficial during initial exploratory phases. The results hint at the possibility that exploratory flights rely more on heuristic strategies, such as systematic search patterns, rather than on learned spatial information. This contrasts with the view of memory as a consistently beneficial trait in foraging strategies. However, the memory implementation in our model—restricted to recalling only the nearest explored area—may not fully capture the complexity of memory usage in real natural environments. Additionally, the absence of key ecological variables like resource distribution and competition limits the relevance of our results. Future research should include these factors and incorporate natural field studies to validate the findings.

In conculsion, this study provides a new perspective on the cognitive processes underlying bumblebee foraging, suggesting that memory may not always benefit exploration. This opens up important avenues for further research on how memory as a cognitive factor influences foraging strategies, with potential implications for pollinator conservation.



References

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