Agent Coordination
Intelligent Systems Lab Assignment

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1 Introduction

In this report, we explore various strategies for coordinating the behavior of wolves in a predator-prey chase scenario. Specifically, we investigate three distinct chasing strategies: **Following Behavior** (**FB**), **Random Role Assignment** (**RRA**), and **Dynamic Role Assignment** (**DRA**). Our objective is to evaluate the effectiveness of each strategy in capturing prey and to identify the optimal approach for constructing a cohesive and efficient wolf-team.

This study addresses the following research questions:

1. What differences in performance exist among the proposed strategies (FB, RRA, and DRA), and which strategy demonstrates the highest level of robustness?

2. How does the imposition of movement limitations impact the efficacy of our most successful strategy?

3. What alterations occur in the stability and predictability of our most successful strategy when stochastic movements are integrated into the wolves' behavior?

2 Methods

2.1 Behavior Strategies

This report investigates the following wolves' behavior strategies:

1. **Following Behavior:** In the Following Behavior strategy, wolves attempt to attack the closest sheep within their vicinity. Each wolf calculates the distance to the target using the Manhattan distance formula:

$$d(x, y) = \sum_{i=1}^{n} |x_i - y_i|$$

This behavior does not encourage collaboration and coordination among the wolves, as they work independently chasing the closest sheep relative to them. We use this strategy as our **baseline**.

2. **Random Role Assignment:** The Random Role Assignment strategy involves assigning the *leader* role to one random wolf at the beginning of each simulation run. All the other wolves become the *followers*. The leader's job is to chase the closest available sheep (determined using Manhattan distance), while the others are trying to come closer to it and catch the prey. This strategy brings some structure to the wolves' behavior.

3. **Dynamic Role Assignment:** The Dynamic Role Assignment strategy, involves, as the name suggests, a dynamic adjustment in wolves' roles. The *leader* role is assigned to the wolf that first finds a sheep. All the other wolves become *followers*. In case the sheep escapes from the leader's proximity, the roles are reset and the same strategy is applied to find a new *leader* and *followers*. This adaptive approach allows wolves to assess the evolving dynamics of the situation

and assign themselves roles that contribute to the overall objective of capturing the prey.

2.2 Communication Strategy: BlackBoard

In addition to the behavior strategies outlined above, we implemented a communication mechanism known as the BlackBoard. The BlackBoard serves as a centralized repository for sharing information among wolves, making possible role management, and collective coordination to catch the prey.

This shared knowledge is leveraged in the **Random Role Assignment** and **Dynamic Role Assignment** strategies, where wolves can optimize their collective behavior and increase their chances of successful prey capture.

3 Hypotheses

3.1 Performance and Robustness

We hypothesize that the **Dynamic Role Assignment** strategy will outperform the other strategies in terms of both prey capture success rate and robustness. We expect this strategy to demonstrate superior adaptability and coordination, leading to more efficient prey captures.

3.2 Impact of Limited Movement

We predict that limiting the movement of wolves will negatively impact the performance of our best-performing strategy.

3.3 Stochastic Movements

We define stochastic movement as choosing to perform a random action, rather than the one imposed by the strategy. The probability of happening that is managed by a constant α. We anticipate that incorporating stochastic movements into the behavior of wolves may result in fluctuations in prey capture success rates and could potentially affect the overall stability of the wolf-team coordination. Also, we may find an α parameter that can improve the median score of our best-performing strategy.

4 Experiments and Results

To investigate the aforementioned research questions, we conducted a series of simulations within a predator-prey chase scenario.

4.1 Performance and Robustness Comparison

For the first research question, we compared the performance and robustness of the three strategies by measuring the number of iterations needed to catch the prey, and their variability. The simulations were repeated multiple times (100) to ensure reliable results (Figure 1), (Figure 2).

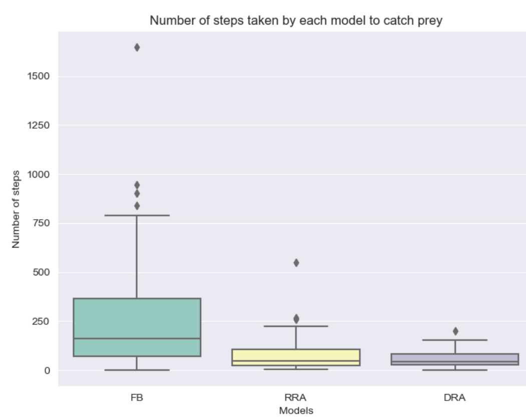

Figure 1: Wolves' Performance Using All Strategies

4.2 Impact of Limited Movement

To address the second research question, we modified the movement behavior of our best-performing strategy (**Dynamic Role Assignment**) by switching from the *moveAll* method to *moveLim*. We then assessed how this constraint affected the effectiveness

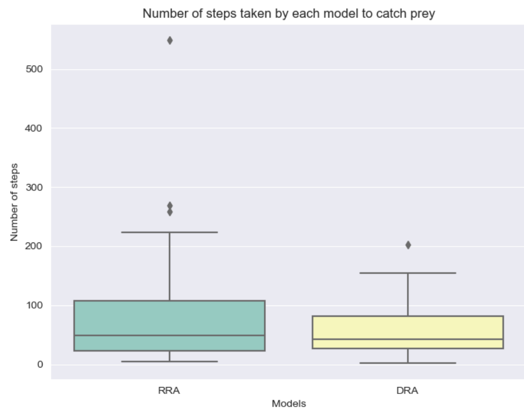

Figure 2: Wolves' Performance Using **Random Role Assignment** and **Dynamic Role Assignment** Models

of this strategy by running the simulation 100 times (Figure 3).

4.3 Stochastic Movements

For the third research question, we introduced stochastic movements into the behavior of the wolves and analyzed the resulting changes in the performance and stability of our best-performing strategy (**Dynamic Role Assignment**). We run the experiments 100 times for each selected α from the range (0, 0.05, 0.1, 0.15, 0.2, 0.25) (Figure 4).

5 Discussion

Capture Efficiency: The results demonstrate that the Dynamic Role Assignment strategy outperformed both Random Role Assignment and Following Behavior strategies in terms of capture efficiency. Specifically, wolves employing the Dynamic Role Assignment strategy required a median of 43 steps to capture the prey, compared to 49 steps for Random Role Assignment and 164 steps for Following Behavior. This significant difference underscores the effectiveness of dynamic role adjustment in facilitating

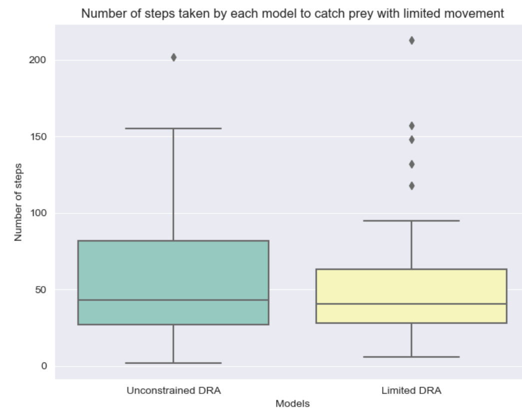

Figure 3: Wolves' Performance Using **Dynamic Role Assignment** (DRA) With Unli

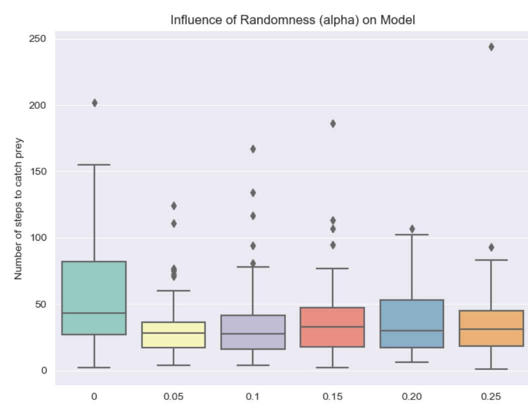

Figure 4: Influence of α on **Dynamic Role Assignment** Model with Stochastic Movement Strategy

quicker prey capture. The collaborative nature of this strategy allows wolves to adapt their roles dynamically, leading to more efficient coordination and pursuit of the prey.

Robustness Analysis: An assessment of robustness across various simulation conditions revealed the Dynamic Role Assignment strategy's consistent performance. Despite changes in prey location and spawn location, this strategy maintained relatively stable capture efficiency. In contrast, the Following Behavior strategy exhibited considerable variability in capturing efficiency, indicating its lower robustness. These findings underscore the importance of adaptive strategies in predator-prey scenarios, where environmental dynamics can influence the effectiveness of hunting tactics.

Limited movement: Our experiments on limited movement revealed that constraining wolf movement has slightly improved the capture efficiency of the Dynamic Role Assignment strategy. Wolves under movement limitations took a median of 41 steps to capture the prey. This increase was marginal, suggesting that the strategy remains robust and effective even with movement constraints.

Stochastic Movements: Introducing stochastic movements had a noticeable impact on prey capture efficiency and coordination stability. Increasing the probability parameter (α), meaning more stochastic movement would be incorporated, generally led to greater variability in capture efficiency among simulation runs, considering non-zero α values. However, our self-defined tuning of α resulted in an optimal value, $\alpha = 0.05$, that improved the median capture efficiency, as well as the variability of the Dynamic Role Assignment strategy, indicating the potential for enhancing strategy performance through stochastic behavior integration.

6 Conclusion

In this study, we explored and evaluated different strategies for coordinating wolf behavior in a predator-prey chase scenario. Through extensive simulations and analysis, we draw several key conclusions.

Firstly, our findings demonstrate that the Dynamic Role Assignment strategy outperforms both the Following Behavior and Random Role Assignment strategies in terms of capture efficiency and robustness. This adaptive approach allows wolves to dynamically adjust their roles based on the evolving dynamics of the chase, resulting in quicker prey capture and consistent performance across various conditions.

Secondly, limiting wolf movement did not significantly affect the number of steps to capture prey for the Dynamic Role Assignment strategy. The strategy showed a marginal increase in capture efficiency and remained robust, indicating its resilience to constraints imposed on movement.

Thirdly, introducing stochastic movements into the wolves' behavior had notable effects on prey capture efficiency and coordination stability. Fine-tuning the probability parameter (α) allowed for optimization of the Dynamic Role Assignment strategy, with an optimal value of $\alpha = 0.05$ enhancing median capture efficiency, as well as variability. This highlights the potential for leveraging stochastic behavior integration to improve strategy performance.

In conclusion, this lab advanced our understanding of coordinated behavior strategies in predator-prey scenarios. By continuing to explore and refine these strategies, we can pave the way for more efficient and adaptive collective behaviors in complex and dynamic environments.

7 Acknowledgements

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