Capturing Hiders with Moving Obstacles

Extended Abstract

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ABSTRACT

The classic hide-and-seek game is an abstraction for many real-world scenarios like capturing intruders in a closed space, locating objects, patrolling an area, etc. Since most of the present work is based on static obstacles, we address solutions for the hide-and-seek game in an environment where the obstacles are not static. We design strategies that would facilitate seekers to capture hiders in an environment with moving obstacles. We have three strategies: *Baseline strategy, Set-cover strategy, and Sweep strategy*, which use different surveillance techniques to be followed by the seekers. We simulate the methods and compare their performance in different scenarios. While the baseline strategy demands many seekers in large environments, the other two strategies, set-cover and sweep, are ideal for applying in large environments as they require fewer seekers in the same environment.

KEYWORDS

Strategies; Hide and seek; Game; Surveillance; Coverage Point; Strategic Point; Moving Obstacles

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1 INTRODUCTION

In this study, we built an agent-driven simulation environment for the game of hide-and-seek with obstacles. The agents are divided into two groups: hiders and seekers. Hiders use hiding spots around obstacles to stay hidden, while seekers try to find the hiders. The obstacles move independently around the environment, making it difficult for the seekers to find hiders. All agents and the obstacles follow specific properties, described in section 2, that guide their interactions with each other and the environment.

We defined two new strategies for seekers to capture hiders, simulated them, and compared their performance. The results were evaluated based on the median number of steps seekers require to find all hiders in a large environment with different types of obstacle movement, as discussed in section 2.2. We simulated the hide-and-seek game and ran it for several steps for our results.

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2 GAME ENVIRONMENTAL

We are given environment (E) divided into a grid of M x N cells containing obstacles and two types of agents: hiders and seekers.

2.1 Agents

The agents are mobile and autonomous individuals with different goals. Hiders aim to stay in the environment as long as possible by not getting caught by seekers, while seekers aim to find all hiders from the environment. The agents have a field of vision (v) that determines the number of cells in the grid they can see. Obstacles block agent's vision irrespective of field of vision. Hiders may hide behind obstacles to avoid being caught by seekers, while seekers keep patrolling the environment looking for hiders. Seekers follow a strategy to find all hiders in the environment.

2.2 Obstacles

Obstacles (O) are objects or blocks randomly placed in the environment. They can be static, remaining in the same cell in the grid throughout the game, or dynamic, moving to different empty cells. Obstacles block the field of vision of agents, and moving obstacles can either help hiders increase their hiding time or trouble seekers by sheltering hiders. Seekers can only catch hiders on the exposed surface of an obstacle within their field of vision (v), as they cannot keep track of all edges of an obstacle simultaneously. Seekers may, however, form strategies to surround an obstacle and capture all associated hiders. We have three types of obstacle movement - hider-friendly, seeker-friendly, and completely random. Hider-friendly movement moves obstacles away from the visibility region of seekers, while seeker-friendly movement prioritizes moving obstacles to cells within the field of vision of seekers. Completely-random movement selects cells randomly. Different obstacle movement techniques are used while evaluating strategies to determine results [see section 4].

2.3 Strategic and Coverage Points

Strategic Points (SP) are hiding points for hider agents, defined on the midpoint of the edge of obstacles. Hiders stay associated with one of the SPs to take advantage of obstacles and remain out of seeker's visibility range.

Coverage points (CP) are ideal seeking points for seekers in the grid, where seekers can take positions to capture hiders. The number of CPs required is determined by the strategy used. Unlike SPs, CPs are imaginary cell positions where seekers can be placed, and their positions are only known to seeker agents.

3 SEEKER STRATEGIES

3.1 Set-Cover Strategy

The Set-Cover Strategy is a surveillance technique that determines the smallest number of coverage points required to track strategic points in an environment. The method considers the seeker's field of vision (v) and the classic set-cover algorithm [3] to minimize the number of coverage points needed and to establish their positions in the environment. An algorithm is provided to compute the minimum number of coverage points required to cover all strategic points, which involves identifying the visible adjacent cells for each strategic point, keeping track of visible adjacent strategic points, and determining all the possible positions of coverage points.

The minimum number of coverage points required can be calculated from the expression $n(CP) = \left\lceil \frac{(m*n)*2}{8*(v*(v+1))} \right\rceil$, where m and n are the dimensions of the environment, and v is the visibility range of the seekers. The expression is derived considering different factors such as visibility overlaps, edge cells, and placing coverage points at a Manhattan distance of v whenever possible.

The Cell Ranking strategy ranks cells when multiple CPS cover the same strategic point(s). It considers the number of new cells that would be tracked by each possible coverage point and existing tracked cells by existing coverage points. This helps to minimize the overlap of tracking area and reduce the rearrangement of points when obstacles move, making it easier for seekers to keep more cells in their combined field of vision.

3.2 Sweep Strategy

The *Sweep Strategy* is a surveillance technique seekers use to locate hiders. It aims to limit the available hiding places for hiders through a surveillance technique where seekers must traverse the entire grid starting from one corner of the given environment, covering all the grid cells and ensuring that no gap nodes are left for hiders to escape. Seekers find all hiders associated with an obstacle by capturing every alternate strategic point in the obstacle that falls under their field of vision. One additional seeker visits the unguarded nodes in subsequent steps. The number of additional seekers required to inspect a particular obstacle depends on the number of strategic points associated with it. The maximum number of coverage points needed during the game is the number of seekers required to keep track of the longest sequence of cells in the grid, which is diagonal in the case of a rectangular environment. The amount of time it takes (in terms of game steps) to finish the game depends on both the number of steps needed to cover the entire grid and the need to monitor each obstacle individually.

4 SIMULATION AND RESULTS

We simulate the two surveillance strategies, set-cover and sweep, for finding hiders in a large environment. The number of seekers provided for the set-cover strategy simulation was lower than required because assigning a seeker to each coverage point would result in all the hiders being caught in one step. Table 1 mentions the number of seekers provided for different simulations of the set-cover strategy as a percentage. The set-cover strategy demands more seeker agents than the sweep strategy to cover the environment. The results from the experiment [Table 1] show that the set-cover strategy effectively captures the targets in a large environment, even with fewer seekers available. On the other hand, the sweep strategy requires fewer seeker agents and effectively captures the hiders with fewer seekers. The experiment concludes that the sweep strategy performs better than the set-cover strategy regarding seeker requirements and game completion time. The simulator code and extended version of the paper can be found here: https://github.com/AYUSHMAN-PANDA/NanSim.

Obstacle Movement	**Set-Cover (3792)**			**Sweep (577)**
	20%	**50%**	**80%**	
Random	2297	1347.5	1071	746.5
Hider Friendly	3234.75	1921	1515.3	1023.71
Seeker Friendly	1369.26	884.741	674.11	618.08

Table 1: Median Game Completion Steps in a 100 x 100 grid across 50 game rounds. The average number of seekers required by each strategy is given in brackets.

5 RELATED WORK

We acknowledge the contributions of past researchers in hide-and-seek games, whose work has paved the way for our research. The hide-and-seek game has found applications in operation research, pursuit-evasion games (Chung et al. [4], Parsons [8], Megiddo and Hakimi [7]), multi-agent security (Pita et al. [10], Fang et al. [5], Paruchuri et al. [9]), and reinforcement learning (Baker et al. [2]). The game with moving hiders was introduced by Isaacs [6] and further studied by Alpern [1], who provided a solution for a generalized case. Recent research in hide-and-seek focuses on emergent agent behavior with the help of reinforcement learning and AI techniques. Strickland [11] proposed reinforcement learning-based strategies in a 3D environment, while Tandon and Karlapalem [12] studied the game in a 2D environment with static obstacles, introducing abstractions like coverage and strategic points.

6 CONCLUSION

The paper studies two effective strategies, set-cover, and sweep, which can be applied in real-world simulations of agents in various environments. This paper builds upon the work of Tandon and Karlapalem [13] on capturing hiders with static obstacles. We introduced new spatial concepts relevant to environments with moving obstacles. We present the results of the strategies in various scenarios, demonstrating that they effectively capture hiders within a reasonable number of steps, even when the obstacles are moving randomly. These strategies use classical set-cover and traversal-based algorithms, which are less computationally demanding and suitable for real-time strategic games. Unlike many existing reinforcement learning-based strategies that require large amounts of training data, these strategies do not need such data. However, there is room for improvement and exploration in future work, particularly in evaluating these strategies with more considerable obstacle sizes and strategic points and considering the possibility of hiders remaining hidden in non-strategic points in the environment.

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