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Title: "A Ghost of a Chance: Polyagent Simulation of Incremental Attack Planning"

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A Ghost of a Chance: Polyagent Simulation of Incremental Attack Planning

Abstract

One technique for improving a C2 planning process is to explore as broad a range of potential scenarios as possible, while intelligently constraining the search space and managing the uncertainty of outcomes. From a modeling and simulation perspective, one novel way to do this is to employ a *polyagent* modeling construct to produce emergent planning behavior. A polyagent is a combination of a persistent agent (an *avatar*) supported by a swarm of transient agents (*ghosts*) that assist the avatar in generating and assessing alternative (probabilistic) futures. The ghosts in the model employ pheromone fields to signal, identify, and act on threats and opportunities relative to the goals, which are then reported back to the avatars for integration and decision-making.

The current work implemented a polyagent model of attack planning in a generic geo-temporal space with Red/Blue forces and multiple targets pursued by Red. The results indicated that Red polyagents enjoy an asymmetrical advantage when force strength and planning behaviors, specifically the number of steps in the future the ghosts simulate, are identical, but that there is an element of diminishing returns to looking ahead more than a few steps.

Paper Outline

1. INTRODUCTION
    a. Brief discussion of agent-based models in command and control problems
        i. Examples from the literature
        ii. Importance of covering as much of the planning space as possible
        iii. Importance of guiding the search over the planning space intelligently
            1. Computational resources may also be an issue
    b. Traditional agent-based modeling limitations: agent can only execute one possible trajectory per run of the system, averaging over individual runs might not be as informative
    c. Polyagent modeling construct [See Parunak and Brueckner, 2006] has potential to address some of the shortcomings of traditional agent-based models
2. POLYAGENT CONSTRUCT
    a. Two key components
        i. "Avatar" is a persistent agent who takes action in the virtual world, and uses results suggested by the activities of its "ghosts" (see below) to decide its next action
        ii. "Ghost" is a transient actor in the virtual world that plays out alternative probabilistic scenarios over some forecast horizon by interacting through pheromone fields (in the present example, the opposing ghosts and the target). They effectively act as "scouts" for the avatar, which allows the avatar to "play-act" different courses of action and integrate the results to decide the next step
3. POLYAGENT MODEL DESCRIPTION
    a. Context
        i. Chose to start with relatively simple attack scenarios
        ii. Red Force, Blue Force, and Single/Multiple Fixed Target Scenarios arranged in a grid configuration
            1. Snapshot of model during a typical run
        iii. The model employs incremental attack planning because it is continually adjusting to local conditions "on the ground", never looking more than one step ahead at a time; no central command and control
        iv. Deployed as a Java-based application
    b. Initial conditions
        i. Random placement of target(s) and Red/Blue forces on grid
        ii. Specified number of Blue/Red polyagents
            1. Explored both symmetrical (equal Red/Blue forces) and asymmetrical (greater Blue forces) scenarios
    c. Agent goals (for both avatars and ghosts)
        i. Red: Avoid Blue forces, seek out target
        ii. Blue: Seek out and destroy Red
    d. Pheromones "flavors" emitted by the ghosts and the target

            i. Green – emitted by the target at a consistent rate, detectable by Red ghosts
            ii. Blue – Emitted by Blue forces, indicating threat to Red forces
            iii. Red – Emitted by Red forces, indicating threat to Blue forces
            iv. All pheromones propagate/spread but also evaporate over time to provide an overall pattern of relevance
    e. Encounters between Blue polyagent, Red polyagent, and Target (i.e., occupy same square of grid)
        i. Red and Blue on same square: Outcome governed by "kill probability" parameter that Red agent dies when encountering Blue, or vice-versa
        ii. Red and Target on same square: Red destroys target and "dies"
        iii. Blue and Target on same square: no change in state for Blue or Target
    f. Algorithms governing next move decisions (resulting in a vector that move avatars and ghosts to the "best" adjacent square)
        i. Ghosts
            1. Red ghosts: Highest green pheromone concentration square – highest blue pheromone concentration square + weighted random factor
            2. Blue ghosts: Highest red pheromone square + weighted random factor
        ii. Avatars
            1. Red avatars: Highest green pheromone square from a ghost still "living" – Highest blue pheromone concentration square + weighted random factor
            2. Blue avatars: Highest red pheromone concentration square reported by all ghosts + weighted random factor
    g. Interpretation of polyagent behavior
        i. Blue: "Take the fight to the enemy" , without directly knowing what enemy is targeting
        ii. Red: Independently operating "cells" (no interaction between avatars); Avoid the enemy, but perform suicide attack when reaching target

4. SIMULATION AND EXPERIMENTAL RESULTS
    a. Key parameters explored (possible range) [default used]
        i. # of ghosts per avatar (0..) [5]
        ii. Kill probability when encountering opposition (0..1) [0.9]
        iii. Forecast horizon (how far ahead ghosts "play act") (0..15 cycles) [5]
        iv. Weight of random factor [0.1] (0.1)
        v. Dimensions of grid (0.. x 0..) [25 x 25]
    b. Measures of success
        i. Red – max # of targets found, max # of surviving avatars
        ii. Blue – min # of targets destroyed
    c. Results overview

i. Equal strength Red and Blue force scenarios (e.g., 10 vs. 10)
    1. Red "easily" hits targets multiple times (within 100 cycles)
    2. Robust across number of forces, ghosts per avatar, etc.
    3. Provide results and graphics from sample and average runs
    4. Intuition: Information Asymmetry: Blue does not know where the target is!

ii. Blue force much larger than Red Force (e.g. 25 vs. 5)
    1. Red success is a function of the forecast horizon both sides use for the ghosts, not so much on the number of ghosts per avatar
        a. Success in reaching targets increases as the forecast horizon approaches 5 cycles, levels or even drops off after that
        b. Interpretation: as forecast horizon increases, ghosts are exploring increasingly unlikely scenarios, so extra information is of limited value or is even misleading
        c. Results are largely independent of the number of ghosts
        d. (Provide detail graphics and data over the experimental runs)
    2. Average cycles to kill all Red avatars also increases up until about 5 forecast cycle horizons and then levels off or decreases
        a. Interpretation: Again, looking ahead further at increasingly unlikely scenarios does not benefit Red
    3. Standard deviation of the cycles to kill is an increasing function of the forecast horizon (interpretation not clear)

iii. Discussion of other parameter variations that could be explored

5. CONCLUSIONS
    a. Polyagent modeling was effectively used to implement incremental attack planning scenarios using the pheromone interaction and the "next move" algorithms
    b. Polyagent modeling provides a novel way of exploring a great variety of probabilistic scenarios in a computationally efficient fashion
    c. Initial results confirm some intuitions about both the benefits of planning ahead and suggest limitations of attempting to plan ahead too far.
    d. More work needed to refine the model and improve its utility in real-world settings

Reference: Parunak and Brueckner, "Modeling Uncertain Domains with Polyagents", AAMAS '06, May 8-12, 2006 Hakodate, Hokkaido, Japan