Genetic Algorithms for UGV Navigation, Sniper Fire Localization and Unit of Action Fuel Distribution

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BBN Technologies has applied genetic algorithms (GAs) to create state-of-the-art solutions for a variety of military applications. Three ongoing projects are presented.

1. Tactical Navigation Planning for Unmanned Ground Vehicles

Recent advances in technologies for the control of unmanned ground vehicles (UGVs) have demonstrated the ability to perform local path navigation while traversing complex terrain, and to perform simple longer-range path planning, such as navigation between human-specified waypoints. However, the challenge remains to develop technologies for that perform global replanning for achievement of higher-level mission goals (e.g., reconnaissance, surveillance, and target acquisition) despite changing environmental conditions, evolving mission requirements, and the need to coordinate multiple UGVs [1].

BBN has developed the Advocates and Critics for Tactical Behaviors (ACTB) system to investigate the global replanning problem. ACTB uses a GA in which a genome represents a plan as a set of paths, one for each UGV, where each path is a variable-length sequence of navigation waypoints. Mission goals are defined as a location or area that must be visited within a time window. The GA searches the space of possible paths using general mutation and crossover operators that add, remove, modify or swap waypoints in a random fashion, as well as domain-specific operators, termed *advocates*, that that modify the paths based on knowledge about good tactics. For example, a road-following advocate may modify a UGV's path by adding a sequence waypoints that lie upon a road. To determine the fitness of each plan, the GA uses a set of *critics* that compute different evaluation metrics corresponding to different tactical criteria of what constitutes a good plan. For example, a critic may evaluate how well all missions are met, or how much danger each UGV is placed (i.e., if too close to a known enemy). Each critic is weighted to reflect the relative importance of its associated tactical criterion, and the fitness is computed as the weighted sum of all critic evaluations.

Figure 1 illustrates an example of replanning performed by the ACTB system in response to the discovery of new enemy locations. The path of each UGV is indicated by a different line thickness, and off-road terrain is white. The new evolved plan (Figure 1b) reroutes the UGVs and reassigns some mission goals to different UGVs in order to avoid the new enemies.

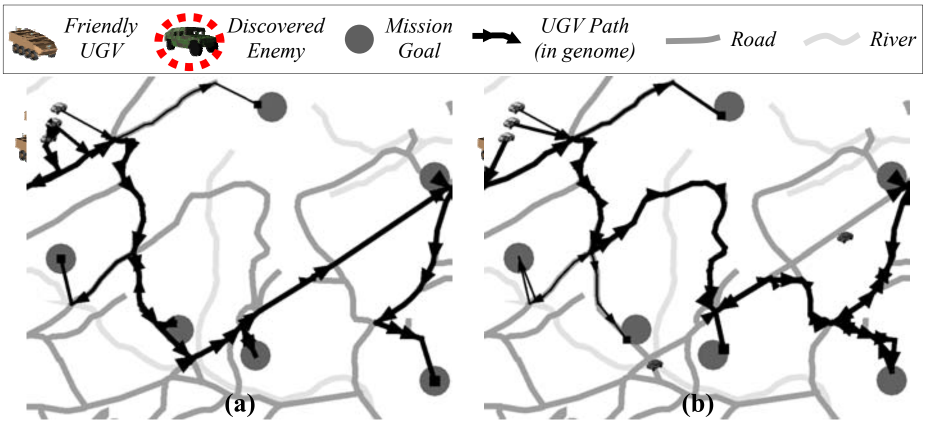

Figure 1: (a) Original (evolved) navigation plan for three friendly UGVs and six mission goals, and (b) New plan evolved after discovery of two new enemy locations

2. Boomerang: Identifying the Source Location of Sniper Fire

BBN has recently completed the Boomerang project, which involved the design, manufacture and deployment of a sniper fire localization sensor system for installation on military HMMVV's (see Figure 2). Fifty Boomerang systems have been deployed in Iraq and have demonstrated highly effective performance in a wide range of operating conditions. Deployment of additional units is ongoing.


Figure 2: HMMVV with two Boomerang sensors mounted on back

Localization of shooter position and bullet trajectory has traditionally been done by combining acoustic detection of shockwave and muzzle-blast detections. In many environments, however, muzzle-blast is either unavailable or unreliable. Estimating trajectory, shooter location and elevation with only shockwave information is not a generally solved problem. Beyond the immediate challenge of solving the equations to produce a reliable solution, the physics of shockwave propagation dictates that there is a natural ambiguity in the solution; that is, the correct solution is often difficult to distinguish from another solution that is very different in geometric (shooter position) space, but very similar in shockwave time-difference-of-arrival (TDOA) space. Further, the solution must be extremely fast, to allow for timely response to incoming shots. [2]

BBN has implemented a genetic-algorithm based solution that explores the space of possible shooter locations and shot trajectories and determines, in real-time, a solution that is disambiguated with high confidence. By using a set of domain-specific mutation and cross-over operators, a solution is achieved by evolving over 10000 individuals in under 400 milliseconds.

3. Fuel Distribution Support in the FCS Unit of Action

The military logistics community requires a scalable, high fidelity simulation capability for modeling the detailed, dynamic, logistics activities of a distributed military organization. BBN is developing a scalable, agent-based modeling system using Cougaar agent technology [3] that represents the logistics activities of the Army's Future Combat Systems' (FCS) Unit of Action (UA). In particular, we have examined the problem of distributing fuel to the combat vehicles within the UA.

In the standard fuel distribution problem, refueling depots are maintained at fixed locations, and the distribution problem is relatively simple since refueling trucks move short distances from the depots to the combat vehicles in the field. In the FCS UA fuel distribution problem, the UA is intended to be self-sufficient for a 72-hour period, during which there is no access to external refueling depots. Instead, all fuel is stored on refueling trucks that directly deliver fuel to the combat vehicles. Further, within the FCS vision, the UA will be highly mobile (e.g., may cross wide distances rapidly) and responsive to changes in operational conditions. As such, the refueling trucks must handle changing demand and move with the combat vehicles.

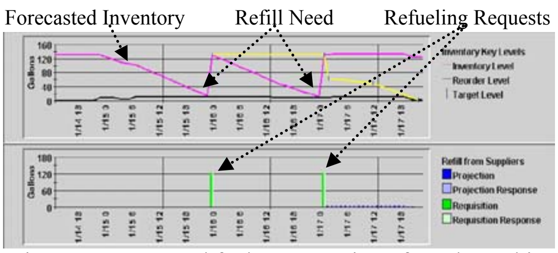

Figure 3: Forecasted fuel consumption of combat vehicle over time and multiple refueling requests needed to maintain readiness for 72 hours

BBN has developed an agent society in which one set of agents model the fuel consumption behavior of the combat vehicles within the UA over time, based upon the planned actions of those vehicles for the operational scenario (e.g., different consumption rates for different activities). These agents generate refueling requests for all combat vehicles (see Figure 3), with possibly multiple requests per vehicle (e.g., if the vehicle is anticipated to require several fill-ups during the 72 hour window). Each refueling request indicates a desired fuel amount, location and time of delivery. A separate scheduling agent uses BBN's Vishnu [4] genetic algorithm software to assign refueling requests to the refueling trucks. The GA optimizes against multiple goals, including minimizing the travel performed by the refueling trucks, minimizing the number of refueling trucks needed and maximizing the number of requests that are satisfied (on time and required quantities). The scheduling agent is continually provided with all updated refueling requests, and evolves a new plan based upon the current location and fuel quantity of all refueling vehicles.

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2. Duckworth, G.L., Gilbert, D.C. and Barger, J.E. "Acoustic counter-sniper system", *SPIE Int. Symposium on Enabling Technologies for Law Enforcement and Security*, 1996.
3. "Cougaar Open Source Web Site," http://www.cougaar.org/.
4. Montana, D. "Optimized Scheduling for the Masses", *GECCO-2001 Workshop: The Next Ten Years of Scheduling Research*, 2001.