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TECHNICAL R E P O R T

Allocation of Forces, Fires, and Effects Using Genetic Algorithms

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Summary

Decisionmaking within the Future Battle Command structure will demand an increasing ability to comprehend and structure information on the battlefield. As the military evolves into a networked force, strain is placed on headquarters and others to collect and utilize information from across the battlefield in a timely and efficient manner. Decision aids and tools on the battlefield, as well as solution methodologies in constructive simulations, must be modified to better show how this information affects decisions.

This report demonstrates how a particular algorithm can be adapted and used to make command and control decisions in analytical planning tools and constructive simulations. We describe a model that uses genetic algorithms in the generation of avenues of approach (AoAs), also called “routes” and “paths,” and the allocation of forces across those AoAs.¹

The model is a representation of planning because it uses intelligence products to determine a preferred route or set of routes and allocate forces to those routes. The intelligence products consist of (1) information about Blue forces, such as their mission and location; (2) information about Red forces, such as their location, capability, intent, and activity; and (3) information about the environment.

We used a genetic algorithm to stochastically search the vast space of possible maneuver schemes (routes) and allocations of forces to these routes. This technique is appropriate for such decisionmaking not only because it can quickly search a very large space but also because it can find “good,” feasible, although suboptimal, solutions without becoming mired in an optimization routine. Because real-world problems are not, generally speaking, convex, we are not guaranteed to find global optimal solutions. Hence, some sort of heuristic, such as a genetic algorithm, is required. To improve the efficiency of our search, we broke the model down into two phases, each of which has a genetic algorithm at its core. The first phase discovers potential routes; the second determines a desirable allocation of forces to those routes.

The model developed in this report is unique in many respects. It incorporates many higher-level intelligence products, such as intelligence about location, activity, intent, and capability, into the planning algorithm.² It also includes information about the intelligence capability and adaptability of the adversary. Although many of these parameters are largely conceptual, our descriptions of them are not. We quantify each parameter in the model and hence parameterize the battlefield.

¹ We use the terms *AoA*, *route*, and *path* synonymously throughout this report.

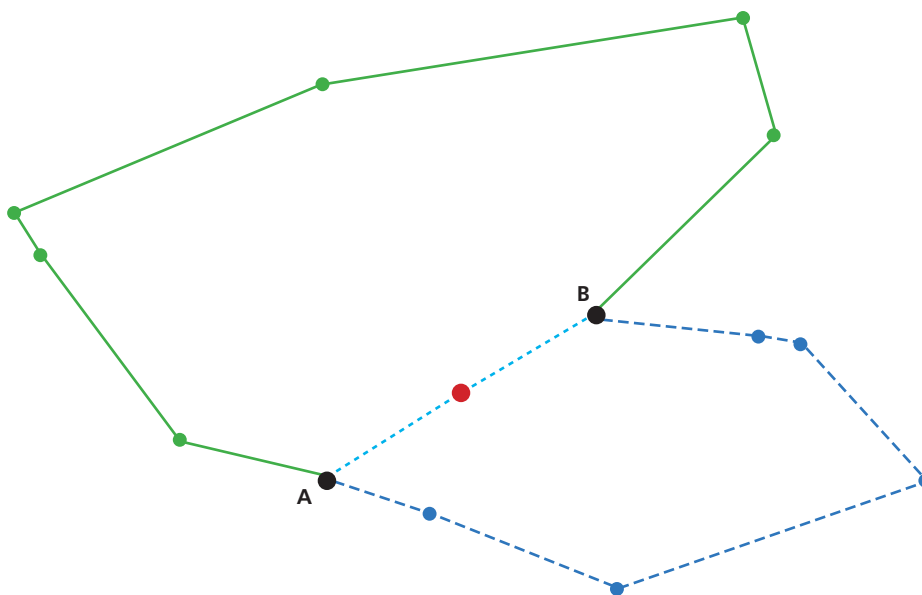
² For additional information about these information products and the fusion of such information, see Pernin et al. (2007).

The employment of such a diverse set of intelligence products allows for sophisticated look-ahead representations of Red forces as opposed to the “static” snapshot representations that are typically used in planning sessions. These more-sophisticated representations of Red forces allowed a diverse set of outputs to occur (see Figure S.1), including the discovery of Blue tactical “feints” with no hardwired heuristic to drive the solution to this famous military tactic.

The model also features terrain representations that affect each side’s ability to move and hide. Terrain is characterized by three parameters: impassibility, inhospitableness, and shadowing. “Impassibility” measures the degree to which Blue finds certain terrain difficult to cross. “Inhospitableness” measures the degree to which Blue believes that terrain will affect Red’s choice of location. “Shadowing” models the influence of terrain on Red’s effect on Blue. As an effect on effect, shadowing is a second-order consideration, and although we have included a description of the effect of shadowing in this report, we do not currently implement the shadowing function in our computer model.

To validate the model, we first considered a simple scenario in which Red was stationary and located at the midpoint between Blue’s start and end points. Blue’s mission was to reach his destination while minimizing his exposure to Red. Routes discovered by the model show that the chosen path depends on intelligence about Red’s location and capability. Specifically, if Blue is relatively certain about Red’s location and capability, then Blue benefits from maneuvering around Red. However, if Blue is very uncertain about Red’s location or capability or both, Blue does not benefit from maneuvering around the enemy, but rather should take the most direct route to his destination. Over various cases, the model clearly demonstrates the value of intelligence in the planning process.

Figure S.1
Tactical Feint as Blue Plans to Move from Point A to Point B to Avoid a Mobile Red



NOTE: Three separate paths are shown in this example. Red starts at the position shown between points A and B.

The model also demonstrates the influence of terrain on AoA selection. We modeled a simple mountain feature that affected both Blue and Red forces. Because Red was less likely to travel over the mountainous area, his effect on Blue was diminished in this region. Hence, we expected this region to be more desirable to Blue. However, the desirability of Blue routes was also penalized by the difficult terrain. Ultimately, the model discovered Blue AoAs that avoided the mountainous region as much as possible while minimizing Blue exposure to Red.

We also considered various other cases to demonstrate the effect of enemy intelligence and adaptability on AoA selection. Enemy adaptability is the rate at which Red receives updates about Blue's route. Enemy intelligence is the amount of information Red receives at each update. Unsurprisingly, Blue is more likely to evade a less adaptive Red than a more adaptive Red. Also, more-intelligent Red forces diminished Blue's options.

We also demonstrated the effect of Blue knowledge of Red activity on Blue force allocation to AoAs. Activity knowledge is the likelihood that Blue knows to which AoA each Red unit has been assigned. We found that with partial activity knowledge, Blue tries to dominate Red where Blue expects Red to be; Blue will also allocate forces where he expects Red not to be. With perfect activity knowledge, Blue can completely avoid the AoA where the dominant Red force is located.

Our model should be of use to those considering command and control representations in combat simulations.