Terrain-Aware Military Planning Agents

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Abstract

Terrain is important, often decisive, in military battles. This concept recurs across numerous historical examples, military theorists, and doctrinal manuals used by armies around the world. This poster discusses how Mission Command Agents, automated agents used to represent the behaviors of military forces in combat simulations, achieve this understanding of the importance of terrain. First, a review of tactical manuals from different nations consistently identified the importance of terrain to observation, fires, and mobility. Based on the unit's mission, the geography afforded, or prevented, these activities with respect to the enemy force. The next step was to build an automated tool that could quickly calculate these effects based on the anticipated positions. The third step was to formulate these quantifiable terrain effects as objectives in a multi-objective search heuristic so that different places could be compared with each other. After excellent results with these techniques in a realistic military planning scenario, the team is further enhancing human-machine collaboration in this area by adding geospatial and military characteristics of terrain to an existing standard for Command and Control – Simulation Interoperation (C2SIM). With this enhancement, the reasoning employed by the agents is more explainable to military observers. It also allows military experts to adjust agent behaviors by adjusting their goals, without the need to change source code, while employing a user interface that they will be familiar with.

Importance of Terrain in Military Battles

> Know the ground, know the weather; your victory will be total. *Sun Tzu, The Art of War*

The importance of terrain is a recurring theme in military history and theory. A commonly cited example is the decisive nature of Little Round Top, a hill commanded by Colonel Strong Vincent's brigade in the Army of the Potomac during the Battle of Gettysburg. It was decisive because it offered advantages with respect to observation of enemy movement, fields of fire into enemy approaches, cover and concealment among the rocks, and an obstacle to enemy attack due to its steep slopes (Scott, 1993). One observer noted:

> …that hill was, as is universally admitted, the key to the whole position, and the issue of the battle, and probably the destiny of the government depended on its occupation. *Jacob Hoke, the Great Invasion*

The classical military theorists Sun Tzu, Antione Henri Jomini, and Carl Von Clausewitz all write on the importance of terrain, each recognizing the advantages offered by certain places on the battlefield (Scott, 1993). The historical and classical importance of terrain persists in modern military doctrine. The US Army manual for intelligence planning devotes multiple chapters to defining the operational environment and its effects on operations. Important concepts include key terrain, observation and fields of fire, and mobility with respect to avenues of approach and obstacles (HQDA, 2019). British doctrine calls out the physical aspects of the land environment as they relate to communications, providing cover from attack, or obstructing and enabling movement (UK MOD, 2023). Russian military doctrine explicitly references the varying effects of different types of terrain, such as desert, mountains, and urban areas, on offensive and defensive operations (Grau and Bartles, 2016). Given the importance of terrain to military battles, artificially intelligent planning agents will need to incorporate these terrain concepts into their planning algorithms.

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Mission Command Agents

Mission Command Agents are tactical decision-making agents that control simulated units in a military training exercise. They automatically search for high-performance tactical courses of action during a training exercise by running an adapted version of the Non-dominated Sorting Genetic Algorithm – II (NGSA-II) to identify diverse Pareto-optimal plans (Mkaouer & Kessentini, 2014). The solution scoring algorithm used to evaluate plans in each generation of NGSA-II must accommodate user specification of terrain advantages and evaluation of those objectives with respect to unit positions and terrain characteristics. We propose accomplishing this by adding terrain concepts to the Standard for Command and Control Systems – Simulation Systems Interoperation (C2SIM) ontology (SISO, 2020) and enabling comparative calculation of how certain positions satisfy optimization objectives derived from these concepts.

Planning Example

Consider the defense of a strong point example in Figure 1. The Mission Command Agent is positioning the threat machine guns (leftmost diamond icon) so that it maximizes fields of fire into an avenue of approach. First, the concepts of "avenue of approach" and "fields of fire" must be added to the C2SIM ontology. An avenue of approach is a path used by an attacking force to get to its objective. In desert terrain these are represented by low areas, sometimes called draws or wadis. Hydrology analysis allows automatic extraction of these areas, represented by the aqua oblong features in Figure 1. To have fields of fire into an avenue of approach, the defending force must be able to fire their weapons into it. This best represented by line of sight, or intervisibility, queries starting from the defender's location into the avenue of approach.

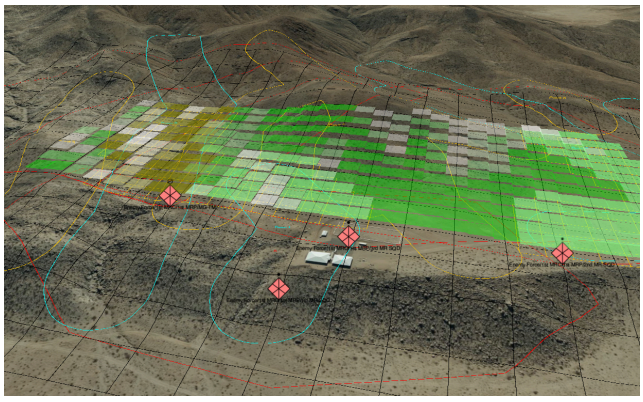

Figure 1. Fields of fire in defense of a strong point.

To use these concepts, the Mission Command Agents must be able to perform spatial reasoning. While these concepts are not available in the C2SIM ontology, merging it with the GeoSPARQL query language brings them in (Car & Homburg, 2022). For example, the olive shaded areas (as opposed to green) represent a geospatial intersection of squares in the defender's concentrated fire area with the aqua avenue of approach. In addition, the darker shades represent areas where the threat machine guns have better fields of fire into this avenue of approach.

Combining features of a geospatial engine, the C2SIM ontology, and the GeoSPARQL ontology allows a military expert to express the defender's objective "Maximize the machine guns' fields of fire into avenues of approach" so that the NGSA-II algorithm can automatically search for courses of action that satisfy that objective, in the context of other objectives and constraints.

Conclusion and Future Work

The geospatial engine supporting Mission Command Agents has been developed and tested. Work is underway for the integration of terrain concepts into C2SIM and the development of an interface to allow military planners to express the terrain-related objectives of tactical tasks so that they can be effectively calculated and clearly explained in a tactical decision-making scenario. This work is advancing the abilities of Mission Command Agents to provide opposing forces that represent a terrain-aware thinking enemy that behaves according to the appropriate military doctrine.

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