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ISOCHRONE MAPS FOR MILITARY GROUND MOVEMENT

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ABSTRACT

A primary objective in contemporary military operations is to streamline planning processes, enabling quicker and more informed decision-making while alleviating burdens on both military and civilian personnel. Our work aims to facilitate this planning, particularly for resupply operations, asset coordination, and predicting enemy troop movements. We use isochrones on a geospatial road network to represent ground unit movement and visualize possible interactions between assets in a given timeframe. How isochrones are shaped, and whether they overlap is information the planner can use for his decision-making. We improve upon existing approaches by implementing a way to represent offroad-travel possibilities of ground assets. The resulting software can be used in military training simulations. Furthermore, we plan to utilize isochrones as action space representations for battlefield simulations.

1 RELATED WORK

Marciuska and Gamper (2010) presents methods for determining objects within isochrones in spatial network databases. It introduces two algorithms to transform an isochrone network into an isochrone area. The first constructs a spatial buffer around each edge, the link-based approach (LB). The second creates a polygon from the outermost edges, the surface-based approach (SB). These methods are compared against a precise baseline algorithm using real-world data, demonstrating high efficiency and accuracy. LB is more accurate but has a higher runtime, and SB is faster but does not evaluate offroad areas within a closed network loop. Several existing software solutions offer implementations of those two approaches. GeoApify (2024) implements an adaptation LB. However, given the sensitive nature of military applications, reliance on commercially hosted software is not preferable. OpenRouteService (2024) implements an adaptation of SB, but lacks the functionality to compute the desirable LB variant. Our solution incorporates both approaches, can run completely offline, and improves upon the LB approach by implementing a decreasing buffer area around reachable roads, representing diminishing offroad-travel possibilities.

2 METHOD

We utilize Python alongside a suite of packages to calculate isochrones. Initially, OSMnx facilitates access to and downloading Open Street Map data as needed. GeoPandas is employed for geospatial data operations, ensuring precise plotting of isochrones. For visualization, TkinterMapView integrates map functionality within Python applications. The resulting GUI allowed us to validate or approach with military subject matter experts (SMEs). Our improved LB approach computes the reachable sub-graph of a given road network, splits its edges if needed for better resolution, and buffers those edges. The applied buffer thickens edge lines to an area by orthogonally adding the remaining travel budget at each edge scaled down by a predetermined factor, representing slower offroad travel speeds.

3 RESULTS

Overlapping isochrones of different groups, whether friendly or hostile, offer valuable tactical insights. For instance, overlapping friendly isochrones suggest optimal locations for supply posts, while intersections

between friendly and enemy isochrones indicate potential engagement zones within a given timeframe. Isochrones offers a more realistic solution than simple straight-line analyses and is more applicable for ground troops. Figure 1 shows one output of our method and its analysis using SB. Figure 2 shows our improved approach using decreasing offroad-travel possibilities using LB.

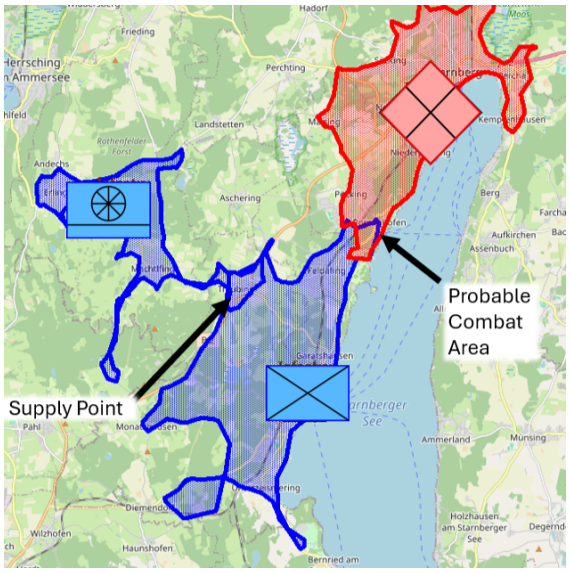

Figure 1: An example of three SB isochrones, two friendly blue units, and an enemy red unit. The blue supply unit on the top left is trying to find a supply point for the infantry unit on the bottom right, which is planning an engagement with the enemy infantry unit on the top right. The isochrones clearly show where it can lead to planned contacts.

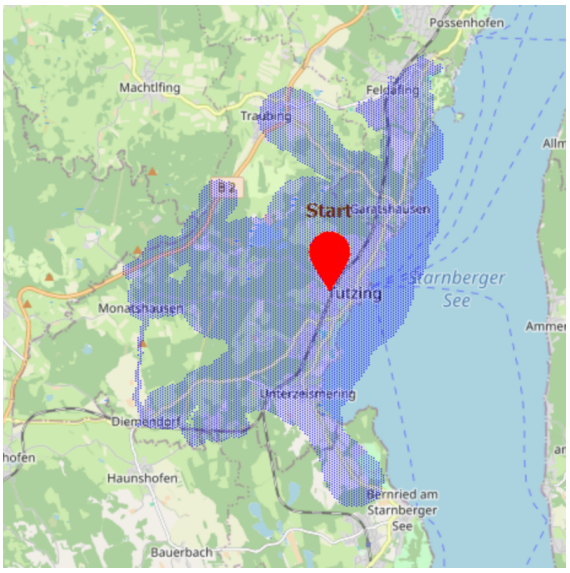

Figure 2: As a ground asset travels, the remaining travel distance gets shorter. If an asset decides to go offroad this results in a reduced travel speed. This logic forms wedges of offroad reachable areas along the edges of the road network. Although being more realistic the main drawback of our approach is the increased runtime.

4 CONCLUSION

Our isochrone-based approach qualitatively enhances military planning by visualizing potential troop movements and interactions. SMEs found our concept appealing, suggesting potential benefits, although further studies are needed to confirm its effectiveness. Our improved LB method offers a more realistic approach compared to established link-based approaches but demands high runtimes. Future work will focus on automating the analysis of overlapping isochrones, refining troop movement capabilities in various terrains, incorporating firing zones, and improving overall runtimes. Improving the interaction with forested areas will also be addressed to enhance accuracy.

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