Logistics Application of Military Land Robotic

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INTRODUCTION

- The ground military robotic (UGV) domain is evolving for more than two decades.
- We could expect that level of automation touching the future military operations will be dramatic .
- One of the decisive components of the future military robots is operational decision-making capability,
- The paper is focused on operational logistics adaptive planning, where UGV swarm is applied to establish a supply delivery chain in the complex operational environment.
- The task is mathematically modelled as operational research (multi-criteria) and intelligence analyses problem.
- Complexity of this field is high and dispersed in several layers, we are at the beginning of understanding of aplication transfer of this problem

RESEARCH GOAL

- Based on the request from the destination points (combat/shooting posts) for the „ammunition“ supply, there is intent to satisfy this request by the available number of UGVs as soon as possible and under the operational conditions and priorities set on the tactical maneuver, balancing the risk of speed and safety, we are minimizing a total „tactical“ cost.

$$\text{Mission Total "Tactical" Cost} \rightarrow min\sum_{i=1}^{N} TSP(UGVi); \rightarrow min\sum_{i=1}^{N} TSP(UGVi);$$

- i – index
- TSP – Traveling Salesman Problem solution within the graph of all nodes to visit, each node has to be visited once by any vehicle.
- UGVi – Particular Unmanned Ground Vehicle

APPROACH TO THE SOLUTION

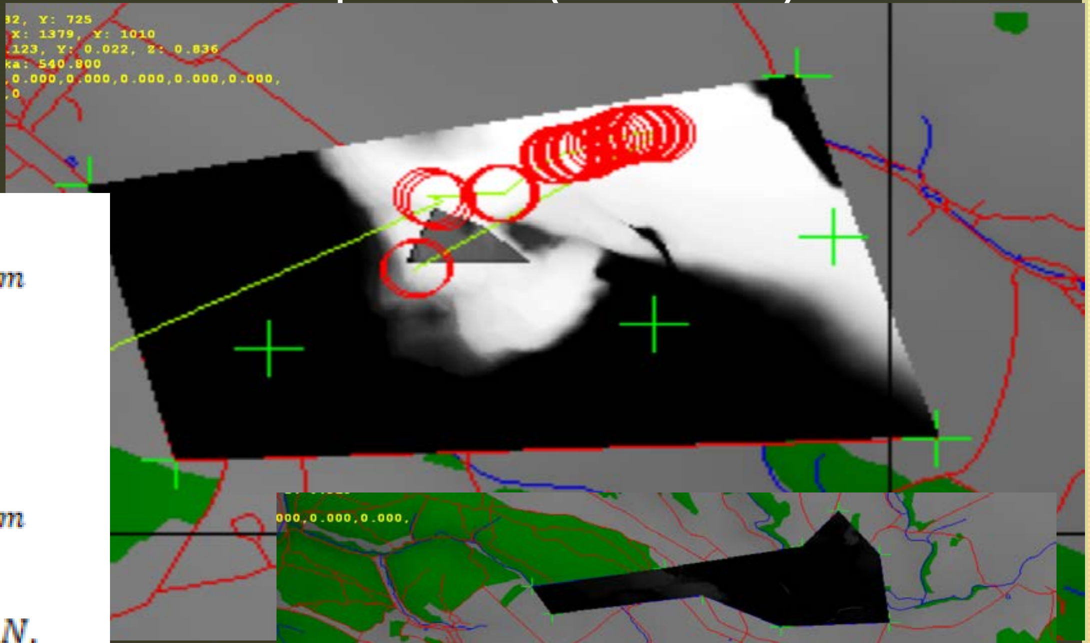
- For initial solution was developed an approach, which could be characterized by six conceptual steps:
  - 1) Selection of operating (source) area and enemy (destination) area, which has to be covered by observation (fire).
  - 2) Operational analyses and shooting/combat post-deployment.
  - 3) Selection of UGVs positions
  - 4) Selection of tactical criteria and capability for each UGV. It has a decisive impact on the „tactical“ manoeuvrability graph arrangement.
  - 5) Calculation of the „tactical“ manoeuvrability graph for each UGV, the graph is composed of nodes and weighted connections. Nodes represent every observation position and initial UGV location, nodes are interconnected by weights representing the „cost“ of the „tactical“ path between each node.
  - 6) Solution of the asymmetric „traveling salesman problem“ (TSP) on the „tactical“ maneuverability graph with 3 UGVs.

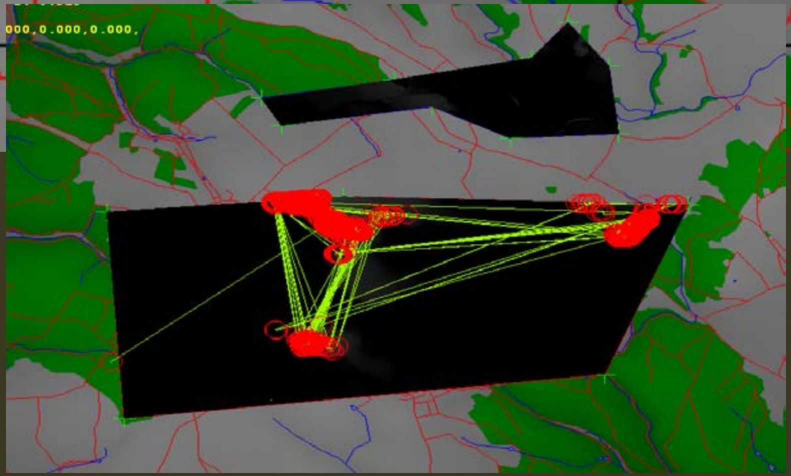
PROBLEM DEFINITION

- In the operation area, there are numbers (N) of UGVs with certain manoeuvre capability and resistance to the enemy fire, there are also a number (M) of destination points for the supply delivery.
- The UGVs are deployed in an operational area and a „tactical manoeuvre" respecting the operational criteria and UGVs capability is required.
- As destination points, we select a shooting/combat post, which has to reflect good visibility to the destination area and visibility of the UGVs manoeuvre is taken into the account within the manoeuvre criteria.
- In this starting case, we simplify the problem to avoid some particular details, such as a size of a particular supply, weight, particular request of each combat post, and load capacity of UGVs.
- There is only one type of supply and there is no strict limit on the UGV number employment, in the other words, even one UGV could satisfy the destination points if necessary (if other vehicles are too far, for instance).

Defense positions deployment

- We simplify the problem in this case as centralized around the visibility issue only.
- The aim of the problem solution is defined as a search of such observation points (from the source area), from which we have a maximal observation coverage of the destination area and the number of these points is low as possible (minimum).
- The problem is defined as:





$$\bigcup_{1}^{n} V_n = \bigcup_{1}^{m} V_m \;; n \in N, m \in M;\; M \subset N, \min \rightarrow m$$

Or, usually we could accept the case:

$$\bigcup_{1}^{n} V_n \approx \bigcup_{1}^{m} V_m \;; n \in N, m \in M;\; M \subset N, \min \rightarrow m$$

V_n $-V_n$ – point set, $V_n \in D, V_n \in D$, visible from n, n $\in N, \in N$,

V_m $-V_m$ – point set, $V_m \in D, V_m \in D$, visible from m, m $\in N, \in N$,

N $-N$ – point set of the source area

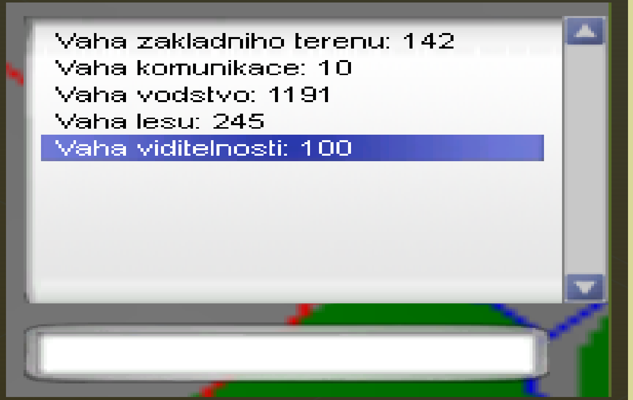
M $-M$ – point subset of the source area

n $-n$ – particular point from N

m $-m$ – particular point from M

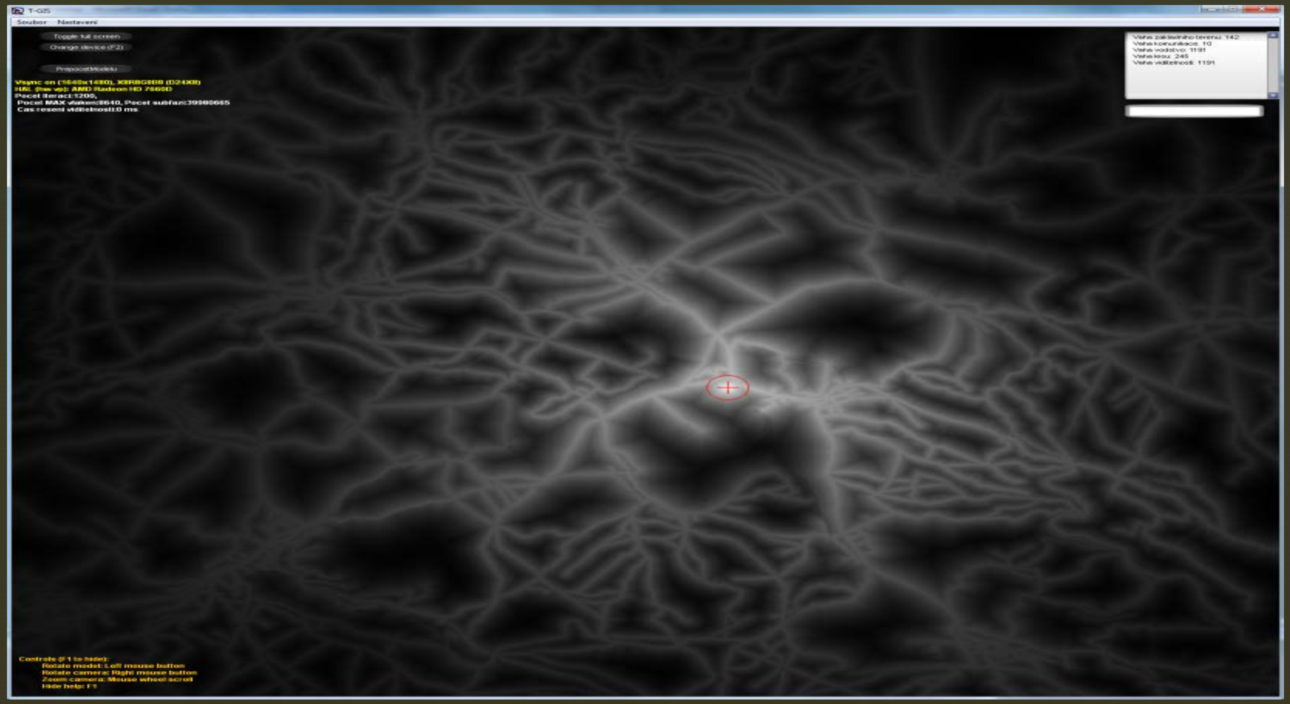
Selection of UGVs positions and tactical criteria for each UGV

- Selection of UGV positions could be done anytime until the optimal manoeuvre solution starts,
- For this example we select just 3 UGVs because computational complexity rises significantly with each UGV, in any case, the solution is independent of any number of UGVs.
- Each UGV could be characterized by a specific manoeuvre and transportation capability with different security constraints.
- Multi-criteria table is generated by the user as a weight imposing a selected cost on the terrain point/area with particular attributes.



„Tactical“ manoeuvrability graph

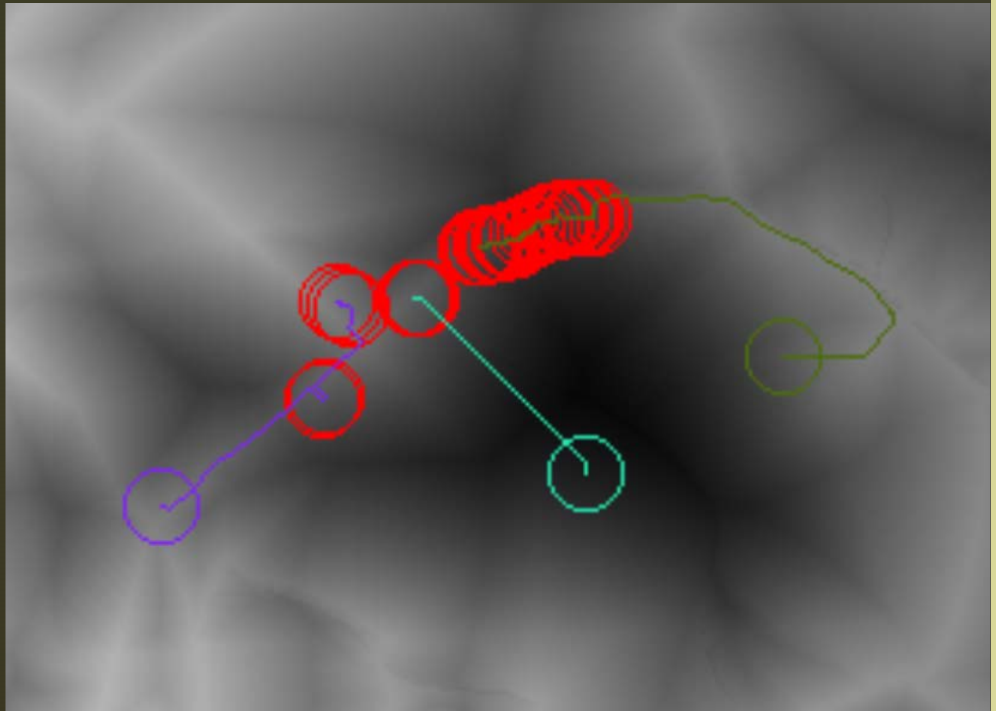
- Calculation of the „tactical“ manoeuvrability graph for each UGV, the graph is composed of nodes and weighted connections.
- Nodes represent every observation position and initial UGV location, nodes are interconnected by weights representing the „cost“ of the „tactical“ path between each node.
- The manoeuvrability graph could be calculated by Dijskra or similar from this class (A-Star) of algorithms.



Solution of the asymmetric „traveling salesman problem“

- The solution of the problem is based on the TSP algorithm, there are many potential approaches or algorithm classes like „Lin Kernigen“, Ant Colony Optimization, Nearest Neighbour, GRASP, and so.
- Because transformation to the „Tactical Domain“ is relatively „tricky“ and thus (mathematicaly) optimal solution could not perform in reality better than other close to optimal solution, for simplicity and initial demonstration just a „nearest neighbour algorithm“ was selected and adjusted to multiple UGVs distribution.
- Algorithm search for the total shortest path of all vehicles vising the destination points.

Remark: destination point has to be visited just once by any vehicle, thus there could appear a situation when only some vehicles are employed, when some vehicle is too far and other vehicles fulfil the task until this vehicle could visit any target point, this vehicle is left apart.



CONCLUSION

- Based on contemporary needs and close future prognosis of a dramatic increase of robotic applications in military operations we develop a relatively “simple” operational logistic problém.
- Eeven though, the initial solution is relatively computationally expensive.
- Based on the state-of-the-art analyses and other sources, we do not see many similar publications dedicated to military ground robotics and thus the research activities in this field are actual.
- We believe that wider recognition of operational problems initiates a broader interest in the “solution infrastructure” and cohesion of the operational and research/technical community.
- It is also apparent, the future battlefield will require full automation of combat activities, where “high level” operational problems play the decisive role.

Way forward:

- It has to be evaluated in practice and incrementally risen the level of complexity meeting the operational needs and situational reality, like load limit per vehicle, asset type-specific delivery, detailed 3D model of the operational environment, interoperability with C4ISTAR systems, supply issuing points incorporated within the path calculation and many other.