

Aalto University

MS-E2177 - Seminar on Case Studies in Operations Research

Optimal Use of Mortar Systems Project Plan

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1 Background

Our client is Defence Research and Development Canada which is the organization responsible for providing technology and advice for the Canadian Department of National Defence, the Canadian Armed Forces, other federal departments, and the safety and security community. The Finnish Defence Research Agency is also involved in the project by providing us the simulation software needed for the research, instructions and study material.

The Canadian Armed Forces are in the process of improving their use of mortars/artillery. The goal of our project is to determine the optimal use of mortar systems i.e., which mortars to use with what ammunition, whether to fire from far or close etc. in some predetermined combat situations. The Finnish Defence Forces has provided us with an artillery ballistics simulation software EETU, that is very accurate but also computationally heavy which results in long run times.

In this project we focus on developing a model that can provide reliable heuristic of simulation results in significantly less time than the simulation software. The model is used to determine the optimal use of mortar systems in the given scenarios.

2 Objectives

2.1 Metamodel

The first objective of the project is to create a mathematical model that can be used to simulate the outcome of a mortar/artillery strike against a near-peer adversary in a predetermined scenario with a limited amount of variables. The model is created using output data from a computationally heavy artillery ballistics simulation software EETU, hence the term metamodel is used of the model developed in this project.

The base scenario is simulating a mortar strike on a RED platoon of three groups of 20 soft infantry targets and three armored personnel carriers (APC) as pictured on Figure 1.

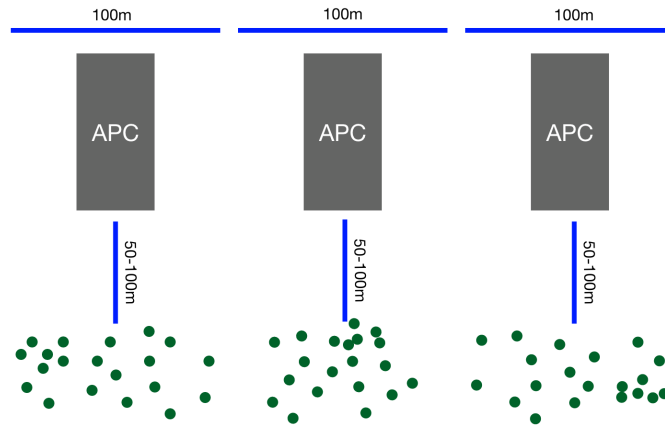


Figure 1: Base scenario

In the initial base scenario, the RED platoon is static and on a level terrain. The BLUE team is on the offence against RED. The BLUE team has two group structures: 2 guns with the combat team at a distance of 2-5 km from the target, or 6 guns in support of 3 combat teams in a rear position at 8 km from the target.

The BLUE team's capacity options are

1. Man portable 81 mm, loading and angle adjusting done manually
2. 120 mm mechanized, soft shell, loading and angle adjusting can be done manually or is automated
3. 120 mm mechanized, armoured, on turret (automated, unmanned) with MRSI capabilities (like AMOS and NEMO).

The BLUE team's ammunition options are

1. Conventional mortar ammunition
2. Precision guided ammunition with coordinate and GPS capability
3. Ammunition with sensors at the end of the engagement to hit the target
4. Combination of coordinate guidance and sensor-based end-phase guidance

The scenarios for the RED team are

1. Static or moving
2. Open field or trenches

The metamodel should be capable of taking the above options as inputs and to output the result of the strike in terms of RED team's losses, or how many targets were hit and how many hits per target were obtained.

The metamodel should closely reflect the simulation results of EETU when used for the predetermined set of scenarios, while being computationally light to enable use in optimization.

2.2 Optimization model

Once the metamodel has been created and its results have been validated in EETU, the second objective is to use the metamodel to construct an optimization model in order to determine the optimal setup of mortar capacity and ammo for the scenario in question.

2.3 The scope of the project

Since there is limited time to finalize the project, the primary objective is to create the metamodel for the base scenario using conventional mortar ammunition. If there is time left after creating a satisfactory metamodel for the base scenario, more variables will be incorporated into the metamodel to account for different permutations of RED and BLUE team's options. If the metamodel can be fully completed within the timeframe, we proceed to the second objective of determining the optimal use of mortar systems.

3 Tasks

3.1 Get familiar with the EETU software and theory

The initial task requires researching available scientific publications related to metamodels, EETU artillery ballistics simulation and military science on offensive mortar fire support methods. Understanding the background is required for running the simulation and later making the metamodels.

3.2 Simulate scenarios with EETU

The scenarios are simulated with the FDFs EETU software. The stationary target scenario is the best starting point as the simplest scenario. Once the scenario is sufficiently accurate the data is saved for later metamodel use.

The initial base scenario requires simulating mortar strikes on a stationary platoon. 3 groups of stationary targets total 20 soft infantry targets with later adding 3 armored personnel carriers (APC).

The infantry are modelled as infantry sized metal boxes in EETU with APCs requiring individual modelling of vehicle weak spots for sensor kill, mobility

kill and destroyed vehicle. A light mortar is unlikely to entirely destroy an APC unless it is a direct hit.

The targets are stationary with no prepared cover and second scenario is dug in targets in foxholes. This affects the likelihood of artillery shell impact especially the shrapnel distribution.

The second scenario is against a moving platoon in a line formation moving along a road.

The scenarios can be made more complex if there is time with addition of terrain height, forest density impact, different artillery shells in addition to 81mm mortar and optionally counter fire impact.

3.3 Investigate metamodel types

This task prepares the metamodeling part. The data gained from EETU is probability distributions and expected values of casualties for individual scenarios. It is required to research how such data can be used for a metamodel simulating similar results to EETU scenarios with just the input parameters instead of in depth ballistic simulation.

3.4 Fit metamodels to the simulation data

The generated simulation data is used to fit metamodels. The task requires the comparison of different models' solutions as well as performing model selection and validation. Later finding how complex scenario is feasible to simulate. The task requires partial completion of simulation data 3.2 and completion of 3.3.

Metamodeling is done with Python or alternative free software based on the customer needs. EETU is usable within Python scripts which makes Python a good option.

3.5 Investigate more complex metamodels with additional scenario parameters

This task explores possibilities for incorporating more scenarios and more parameters based on the customers' needs and previous results.

4 Schedule

Because of the experimental nature of the project, some tasks may have to be iterated multiple times.

The first task, outlined in section 3.1, has been completed as part of the project planning process in January and February.

Rest of the tasks, 3.2 through 3.5, form a sequence that can be iterated multiple times. As explained in section 3.2, the scenario being simulated and modelled can be made more complex, but there is no reason to do so if a simple scenario cannot be modelled with a metamodel.

During the project, one iteration the tasks 3.2 through 3.5 will be referred as a cycle. The first cycle begins with the submission of this project plan, and is aimed to be completed by the second excursion on 12th of April along with the interim report. The second cycle will begin after the submission of the interim report, and be completed in time to compile the results of the project into the final report.

As it is difficult to gauge the time to run the simulations and fit the metamodels, this initial plan estimates that two cycles will be carried out. However, if the data collection and model formulation is faster than estimated, completing three or four cycles may be possible. This would be ideal, as this would allow investigating more complex scenarios.

5 Resources used

5.1 Practicalities

To make sure that the project proceeds apace, the project manager calls a weekly meeting on Mondays. These meetings can be held online via Zoom or Teams, or on-site if most of the team can make it. Additionally, every other weekly meeting will be held with the clients from Canada with experts attending to clarify the client's vision for the end product.

Communication with course staff and clients happens through email. The project group has a Telegram group to facilitate faster response and reaction times.

5.2 Tools

As stated in above sections, the project will heavily utilise the EETU simulation software to gather data about the model being modelled as a metamodel.

Due to wishes from the client, the practical part of the metamodel will be implemented in a free and open-source programming language, e.g. Python.

6 Risks

The main risks related to the execution of the project are listed in Table 1. The risks and their effects are defined, and their probabilities and impacts are estimated on a discrete scale [Low, Medium, High]. Means of mitigation are presented respectively for each risk.

Table 1: Main risks related to the project.

Risk	Effect	Probability	Impact	Mitigation
Metamodel not able to describe the scenarios	Results given by the model are unusable for the client.	Medium	High	Start with simple scenarios and add variables later on. Infeasibility of a general model is also of interest to the client.
Long simulation times of scenarios in EETU	Data gathering and model validation becomes very time consuming.	Medium	Medium	Reserve more time for simulations and develop a script for automatic data gathering.
Scope too broadly defined	Developing the model takes too much time and the model might not be finished.	Low	High	Make sure that the scope is not too large. Start with simple scenarios and broaden the scope if there is time.
Communication challenges with the client	Insufficient feedback for our model, which will make updating the model difficult.	Low	Medium	We have arranged fortnightly meeting with the client to receive feedback and discuss further steps.
Team member inactivity	Workload will increase for some team members, or we will fall behind from schedule.	Low	Medium	Active discussion in the team's communication channel along with even and clear distribution of work.
Exposing military secrets	Information will leak to outside personnel and we might face criminal charges	Low	High	Maintain high operations security if given classified information.