

Aalto University

MS-E2177 - Seminar on Case Studies in Operations Research

# Optimal Use of Mortar Systems Interim Report

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# **1 Introduction**

This report explains the project progress, and the most impactful problems faced during the first half.

## **2 On the EETU simulator**

### **2.1 Gathering data for the metamodel**

As outlined in our project plan, gathering data is the foundation of our project because this data will be used for fitting the metamodel. We have started this process with our initial scenarios. To obtain variation between the different parameters, we have constructed scenarios from which we collect the output data. Each scenario is run multiple times while shifting the center of the aim slightly each time, as slight deviations can lead to significant changes in results. Because of the considerable time taken by data gathering, we have divided it among the team members.

### **2.2 Determining simulation parameters**

Determining and adjusting the simulation parameters has been a large focus of our meetings with the client. There has been a lot of discussion on what parameters to include in the simulations with the goal of finding a combination of parameters that gives realistic enough results without making the modeling unnecessarily difficult for us. After all, our approach throughout the project has been to begin with a simpler model before advancing to more complex ones. This strategy ensures that we attain measurable results at each stage of development.

Currently, the parameters we are considering in the simulations are shooting distance, ammunition size, number of shots, target type, target behaviour, targeting accuracy and terrain. In the first round of simulations we have fixed the values of target type, targeting accuracy and terrain as a result of the discussions we have had with the client and among team members.

The choice of parameters has also been affected by technical aspects. For example, the terrain parameter has some limitations from our end because we do not possess the resources to create a three-dimensional battlefield with different sizes of rocks and other objects. Thus, we have had to find workarounds to achieve similar results.

## 2.3 Problems encountered

Main problems encountered have been related to data gathering with EETU simulations. These have been mostly technical issues with the software use. There has in addition been some issues defining values for some scenario values.

Gathering data from large amount of scenarios has been more work than expected since running multiple scenarios with python command line is difficult, with the software using old depreciated python version. A potential fix would be to run virtual old python environment with matching versions of the required python libraries. However, this has been so far deemed too much work, instead we have been gathering data with the graphical user interface.

Another problem encountered was related to transferring scenario files between project members. The save file system of the software has file path references that depend on the software install location and the user's folder and Windows configuration. Opening a scenario made by another person requires manually editing file path references in a save file. This was alleviated by finding where in the document these references are and manually switching the references with the notepad search feature. For second round of data gathering it would be good to standardize team members' EETU install locations.

Simulating the foxholes is more work than expected, since the official method would be to edit the terrain data file and modifying the ground elevation to produce the foxholes and placing the targets in these coordinates. There is a large amount of work in finding the exact coordinates of the targets from the simulation file and then manually modifying a very large terrain data file. This would then need to be repeated every time a target is moved. The solution to the problem was to make a custom smaller target by modifying the software's target data base files which avoids the ground editing part.

Calculating suitable angles of fall values has been challenging due to the accurate value depending on projectile launch speeds which are not public material. This was solved partially solved with additional info from FDF.

We were able to contact additional EETU experts from FDF for additional information on the EETU. This will help the future data gathering. The manual work in simulating things with EETU was recognized initially as one of the reasons for the need to create a metamodel.

### 3 Gathered data

We have sampled data from a few scenarios from the EETU simulation software to ensure the simulator is operating as expected.

The scenarios we modeled and gathered data from were

1. Firing 24, 30, and 36 rounds using 81mm mortar at soft infantry targets in foxholes on an open field from a long distance.
2. Firing 24, 30, and 36 rounds using 81mm mortar at soft infantry targets standing on an open field from a long distance.
3. Firing 24, 30, and 36 rounds using 120mm mortar at soft infantry targets standing on an open field from a long distance.

The projectile's angle of attack was 45 degrees and the terminal velocity was 300 m/s in each scenario. The radius of the target area within which the strikes were spread out uniformly was 159 meters. Each scenario was run 5 times, and the data was stored in a spreadsheet.

A sample of the data is presented in Table 1. EL refers to Expected Loss, which is the probability of a target kill. Each column from EL 1 to EL 5 represent the expected loss of the corresponding infantry targets in the corresponding simulation.

The results of the scenarios with different variables such as rounds fired, mortar shell type and whether the target is standing or in a foxhole seem logical. The higher the caliber or the more shots are fired, the greater are the expected losses, and the more exposed the targets are, the higher are their expected losses.

In general, the expected losses seem low: even a high number of rounds fired with a heavy, 120mm mortar yields only modest expected losses that are not greater than 39% for any target in any simulation. The reason for that needs to be studied further, but one explanation might be the low angle of attack which has a significant impact on the lethality of a mortar strike.

Table 1: 36 rounds of 120mm mortar at soft infantry targets standing on an open field from a long distance, 5 simulations

| Target        | Squad | EL 1 | EL 2 | EL 3 | EL 4 | EL 5 |
|---------------|-------|------|------|------|------|------|
| Infantry      | Red1  | 0.22 | 0.22 | 0.22 | 0.21 | 0.21 |
| Infantry_copy | Red1  | 0.38 | 0.38 | 0.38 | 0.34 | 0.38 |
| Infantry_copy | Red1  | 0.32 | 0.32 | 0.32 | 0.32 | 0.33 |
| Infantry_copy | Red1  | 0.36 | 0.35 | 0.35 | 0.35 | 0.37 |
| Infantry_copy | Red1  | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 |
| Infantry_copy | Red1  | 0.38 | 0.38 | 0.38 | 0.38 | 0.39 |
| Infantry_copy | Red1  | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 |
| Infantry      | Red2  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| Infantry_copy | Red2  | 0.20 | 0.13 | 0.16 | 0.21 | 0.24 |
| Infantry_copy | Red2  | 0.25 | 0.23 | 0.24 | 0.26 | 0.29 |
| Infantry_copy | Red2  | 0.34 | 0.32 | 0.33 | 0.35 | 0.36 |
| Infantry_copy | Red2  | 0.36 | 0.36 | 0.36 | 0.36 | 0.37 |
| Infantry_copy | Red2  | 0.37 | 0.37 | 0.37 | 0.37 | 0.38 |
| Infantry_copy | Red2  | 0.38 | 0.38 | 0.38 | 0.37 | 0.38 |
| Infantry      | Red3  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| Infantry_copy | Red3  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| Infantry_copy | Red3  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| Infantry_copy | Red3  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| Infantry_copy | Red3  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |
| Infantry_copy | Red3  | 0.38 | 0.38 | 0.38 | 0.38 | 0.38 |

## 4 Building a metamodel

After we have overcome the challenges with data collection from EETU, and we have an initial somewhat complete set of data, our next area of priority will be the metamodel development. As described in the project plan, the objective is to develop a mathematical model to simulate the outcome of the scenario. The first version of our metamodel will take as its inputs the simulation parameters described earlier, and the output should yield similar results compared to the EETU simulator.

The exact process of the metamodel development is yet to be determined, but it will consist of fitting the simulation data to suitable mathematical models, utilizing machine learning methods, with the goal of finding the model that best describes the situation. The model will be developed in phases, starting from more simple scenarios with less variables and expanding towards a more general model. Validation of the model will be performed throughout the development process to ensure the results are in fact usable. The implementation of the model will be executed with Python to allow suitable usage for the customer side as well.

## 5 Initial plan and results

In the project plan, we estimated that the first cycle, a round of iteration consisting of data gathering and model fitting, would be completed in time for this interim report. For the reasons explained above, we have not managed this. In addition, a significant amount of time was taken up by natural delays in communication when asking for help with problems not foreseen at the time of the project plan.

As we now have experience with the data gathering process and know it takes a considerable amount of work, part of the team will be attempting to build the first iteration of the metamodel while the rest run more complex simulations and gather more data to enable a more comprehensive model. With this division of tasks we try to catch up on the initial schedule. It is very probable that only two cycles can be completed in time for the final report.