War and Peace: Modelling the Battle of 73 Easting

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Figure 1: Destroyed Type 69 Iraqi Tank during Operation Desert Storm [2]

ABSTRACT

The Battle of 73 Easting marks the last of tank battles in modern warfare with the decimation of the Iraqi forces by the UN coalition at the tail end of the Gulf War, even though the Iraqi forces had an overwhelming numerical advantage. Could they have foreseen this tragic outcome if they had the advantage of modelling and simulation? This tutorial aims to answer that question by examining 3 different approaches to modelling, Continuous Time Modelling, Markov Chain Modelling, and Agent Based Modelling, with each subsequent approach incorporating a larger range of factors. The input for each model will be held consistent and the goal is to examine if they are able to predict the outcome of the battle given only the initial conditions. Once the parameters have been verified, further research into hypothetical situations and actions can then be investigated.

1 INTRODUCTION

On 26 February 1991 [10], the last large scale tank battle ever fought took place between the UN coalition forces against the Iraqi Armored Division as part of Operation Desert Sabre. The result was the decimation of the Iraqi forces, with them losing 160 tanks compared to the UN forces losing none of their tanks even though the Iraqi forces had an overwhelming numerical advantage. If the Iraqi commanders could have modelled this battle before hand and foreseen this outcome, would they have chosen a different course of action?

Modelling and simulation thus play a huge role in the military domain and the United States even has a dedicated entity, the Modeling and Simulation Coordination Office, towards developing and implementing accurate simulations [3]. The benefits of a successful prediction cannot be understated, but its definitely not the sole benefit of a precise model. The use of a model facilitates the testing of hypothetical questions [12], the what-ifs that could possibly flip the narrative, without having to spend resources on physical war games. Some hypothetical can even be physically impossible to conduct without significant risk.

This tutorial hopes to emphasize these benefits and difficulties faced when applying the various models when applied to a military battle and this process will cover the development of the models in increasing granularity, increasing in complexity by incorporating additional factors with each subsequent model [11].

1.1 GitHub

The tutorial can be accessed at https://github.gatech.edu/yquek3/CSE6730_Spring2020_73Easting

2 LITERATURE REVIEW

Determining the outcome of a battle has always been the primary goal of a military simulation and a myriad of methods to so have been devised since the concept of tactics was introduced [5]. However, not all models are built the same and models developed earlier, when weaponry and technology was still in its infancy, tend to be much simpler as battles are usually dominated by one-on-one melee duels. Lanchester's Laws, developed in 1916 [6], are a prime example of the school of thought of that era as the models developed from these times were simpler, with less factors being incorporated. Research done into applying such older models into modern battles often encounter large fitting errors, as in the modelling of the Battle of Kursk [9].

The arrival of machines of war such as tanks and machine guns however, soon changed the face of war, leading to the development of more complex models. These models attempt to account for a larger amount of factors, from the quantitative features like weapons, to qualitative ones such as morale [13]. Ultimately, the complexity of modern warfare far outstrips the possibility of a precise model and a large stochastic element needs to be introduced to account for this variability. Models that are able to incorporate this variability, such as in a Markov chain [4], are thus better able to approximate a likely outcome. Agent based models take this step further as incorporating independent thought into the individual agents allows self-organizing behavior to be more evident without having to completely grasp the analysis of the full system of systems [1]. This can thus be seen as the gold standard of modern military gaming.

Particularly for the Battle of 73 Easting, the most comprehensive simulation efforts was conducted by the Defense Advanced Research Projects Agency (DARPA) together with the Insitute for Defense Analyses (IDA) . Just 6 months after the conclusion of the battle, DARPA had fused terrain data with the force composition to produce a simulated recreation of the battle. This is akin to agent based model, with each agent following a programmed mission profile. However, given the state of technology in 1991, they were severely limited by the available memory for each simulation [11].

3 PROBLEM DESCRIPTION

Operation Desert Sabre started on 24 February [15] and encompassed the entire coalition's efforts in counterattacking Iraq by crossing the border from Kuwait. The Battle of 73 Easting, in particular, refers to a few hours of the 3rd day of this operation when the 2nd Armored Calvary Regiment advanced from 70 Easting to 73 Easting at 1545H, meeting the Tawakalna 18th Mechanized Brigade and the 9th Armored Brigade.

3.1 Model Input and Output

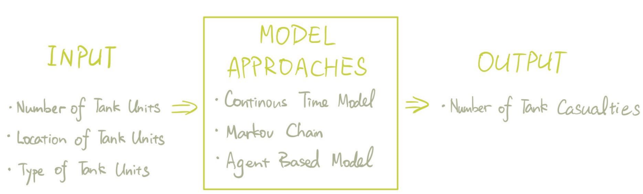

Figure 2: Conceptual Model

Giving the context of the battle, the input of each model can be seen as the number, strength, and location of each tank. From these parameters, the model will then output the predicted number of casualties on both sides. For the Battle of 73 Easting, the number of units on both sides are listed in Table 1 and 2 [11].

Table 1: UN Coalition Forces

Model	Count
M1A1	123
M2A2	116
155MM How	72
MLRS	9

Table 2: Iraqi Forces

Model	Count
T55	35
T62	265

3.2 Assumptions

(1) All armored units are homogeneous and have the same equipment as other tanks of the same model.
(2) Infantry fire is negligible due to their low numbers and low effectiveness against armored vehicles.
(3) The theatre for the battle is limited to a small area between 70 and 73 Easting.

3.3 Aim

The aim of this tutorial is to simulate the Battle of 73 Easting under the above conditions by determining the parameters of each model. Each model will then be evaluated on

(1) Accuracy compared to the final product
(2) Ease of modifying the model to account for hypothetical situations

4 PLATFORM

This tutorial is built on `jupyter` using Python 3.8. Graphs will be built using the `matplotlib` library. The agent based model will leverage on an existing python library, `mesa`.

5 APPROACHES

This tutorial will focus on three different approaches

(1) Continuous Time Model using Lanchester's Laws
(2) Markov Chain Model
(3) Agent-Based Modelling

5.1 Continuous Time Model

In 1916, Lanchester observed that in modern warfare, with guns and not swords, multiple units are able to direct their fire at a single enemy and developed the square law. He postulated that the rate of decrease in an enemy's number of troops is directly proportional to the the number of troops multiplied by their effectiveness [8]. Mathematically, with F and E representing friendly and enemy forces respectively and f representing the force effectiveness of friendly forces

$$\frac{dE}{dt} = -Ff \tag{1}$$

Furthermore, the force effectiveness f and e can be determined by multiplying the number of shots possible per unit time, multiplied by the probability of each shot being a kill.

$$f = r_F p_{kill,F,E} \tag{2}$$

where r_F is the rate of fire of friendly forces, and $p_{kill,F,E}$ is the probability a fired shot from a friendly unit kills an enemy unit. A close examination of this model reveals that the largest challenge in producing an accurate model is the determination of $p_{kill,F,E}$ as r_F is largely constant and unaffected by external factors. $p_{kill,F,E}$

however, can be affected by a large array of factors, from external factors such as the weather or terrain, to soft factors such as crew training and morale.

For the purpose of this tutorial, the empirically tested probabilities will be used as the initial value from which the parameter will be tuned. The deviation required for an accurate model can then be found and an analysis will be conducted to determine if such a deviation was realistic given the ground conditions at that time.

The model is a continuous time model with each step dt being infinitesimally small. However, this is not feasible when programming a real system and thus the model needs to be discretized. This can be achieved [14] by setting

$$\Delta(F) = F + \frac{d}{dt}(F)\Delta t \tag{3}$$

5.1.1 Additional Assumptions. The process of utilizing a Continuous Time Model require the following assumptions

(1) Terrain effects are not accounted for.
(2) Environmental effects are not accounted for.
(3) Tactical decisions are not accounted for.
(4) Only the tanks are considered as units with force effectiveness. The Lanchester Laws do not have a inherent method to account for heterogeneous forces with multiple types of units.

5.2 Markov Chain Model

An improvement on a simple continuous time model, a Markov chain model includes stochastic elements related to a kill chain within a battle. When two individual tanks are placed in a battle, there is a chain of probabilities that is guided by the state the tank is in and its given parameters. For example, when idling, there is a probability that the tank will detect an enemy within range and if it does, a probability its shot hits, and a probability the shot does damage. Each successive state is only dependent on the previous state, with the final outcome being a probabilistic model. This model however, does not account for the spatial element where elements such as terrain and tactics cause states to be codependent on more than one previous state.

5.3 Agent Based Model

An Agent Based Model [7] inherently incorporates a larger variety of factors as compared to previous two approaches and supports a heterogeneous mix of agent types, as opposed in a homogeneous continuous time model. Additionally, its focus on low level, individual movements only produces a consistent result if a strong self-emergent property is present. For this model, we will be modelling all armored units as its own type of agent with its own unique set of parameters as seen in Table 4. The terrain can also be taken into account by blocking line of sight to prevent detection, as well as to modify movement speeds due to slopes and inclines. A slope can also improve or hinder the range of engagement, depending on the direction faced.

Table 3: Armored Agent Parameters

Parameter	Description
v	Movement speed
r_{detect}	Detection range
r_{engage}	Engagement range
p_{hit}	Probability of hit
hp	Health of unit
dmg	Maximum damage
def	Defence
$flee$	Health threshold to flee

Table 4: Terrain Parameters

Parameter	Description
$slope$	Penalty or boost to movement and r_engage depending on direction of slope and target
$cover$	Blocks detection by limiting r_{detect}

Algorithm 1 Main Control Algorithm for Armored Units

```
function STEP
    if hp < flee then
        FLEE
    else
        if enemy.position < self.r_engage then
            self.enemy = enemy
            FIRE(enemy)
        else if enemy.position < self.r_detect then
            MOVE(enemy)
        else if ally.underFire then
            MOVE(ally.enemy)
        end if
    end if
end function
```

Algorithm 2 Fire Procedure for Armored Units

```
function FIRE(enemy)
    if RANDOM < self.p_hit then
        enemy.hp− = (self.dmg − enemy.def)
    end if
end function
```

6 CURRENT STATE

6.1 Code

The pseudocode for the Agent Based Model and the Continuous Time model has been completed and reflected in the above report. The analysis for every model has been completed as well. What remains to be done includes the conversion of the code to a step-by-step tutorial format and the final implementation. The jupyter notebook with the existing code can be found in the GitHu repository.

6.2 Division of Labor

Table 5: Division of Labor

Member	Report	Code
Chuyun	Continuous Time Model, Discussion	Continuous Time Model
Youyi	Markov Chain Model, Conclusion	Markov Chain Model
Yong Jian	Agent-Based Modelling, Discussion	Agent-Based Model

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