# AGGREGATE COMBAT MODELLING USING HIGH-RESOLUTION SIMULATION: THE "MEETING ENGAGEMENT" SCENARIO AS A CASE STUDY

**Sumanta K. Das, Pankaj Sati, and Rajiv Gupta[1]**

**Abstract. This paper illustrates a methodology for developing aggregated combat models using high-resolution simulation and the Markovian Lanchester process. The details of mathematical models involved in a high-resolution simulation process of a "Meeting Engagement" tactical scenario are presented, along with theoretical discussion on the Markovian Lanchester model. The output from the discrete event simulation model is used to estimate the attrition rates for an aggregated Lanchester model. A comparative study of various statistical estimation methods suitable for such estimation is also presented.**

## INTRODUCTION

Defence planners and decision makers use mathematical models to predict likely outcomes of combat dynamics. These mathematical models are generally represented in the form of a system of deterministic differential equations, which represent the gradual interaction and attrition process of the two sides. Lanchester in 1914 first introduced the concept of combat modelling using differential equations [1]. Many analysts have subsequently modified his original work to represent combat dynamics in modern warfare. Weiss [2] modified Lanchester's original work for aimed fire (such as by armour). Brackney [3] introduced the concept of area fire (such as by artillery). Helmold [4] has given a general form for homogeneous-force attrition rates (square / linear / logarithmic) and proposed a modification of Lanchester equations for modern warfare to account for inefficiencies of scale for the larger force when force sizes are grossly unequal.

Obtaining numerical values of attrition-rate coefficients (the rate at which an individual weapon-system type kills enemy targets of a particular type) is a major problem for applying the Lanchester model in practice. Two approaches have been originated in this respect [5]:

- use of analytical sub models, of the attrition process to compute the desired numerical values; and
- a statistical estimate, based on 'combat' data generated by a detailed combat simulation.

In reality, actual historical combat data is not easily available. Therefore, the practice is to use data generated either by combat field experiments or by a high-resolution combat simulation. In the latter approach, one uses combat data to compute statistical estimates of the attrition rate coefficients.

There are four principal statistical methods for computing such point estimates [6]: (a) method of moments estimation (MME) (b) maximum likelihood estimation (MLE) (c) Bayes estimation (BE) and (d) least square estimation (LSE). Of these four methods, only maximum likelihood estimation method has been used extensively for estimating attrition rate coefficients from combat simulation [7–11]. Since the original work of Clark [7], no significant theoretical improvement in the combat simulation approach has appeared in the open literatures. Clark in his work had assumed that every target type on a side had the same target availability for estimation of model parameters. He used the time gap between two successive casualties in his simulation for statistical estimation of the model parameters. There are no alternatives to such assumptions [12–13]. However, Taylor [11] has shown how to estimate attrition rate coefficients, without assuming that all target types on a side have the same target availability.

Comparison of high and low-resolution models and the need of aggregation are elaborated in the literature [14]. High-resolution modelling involves detailed design, high-resolution knowledge usage, narrow in-depth analysis for accuracy, reasoning and comprehension at a more atomic level, and simulating reality. Contrary to this, low-resolution modelling involves simplistic design, low-resolution knowledge usage, responding to mainly high-level questions, reasoning and comprehension with high-level variables, and abstracting "big picture". High-resolution modelling can also be used for informing, calibrating, or explaining low-resolution work.

The taxonomy of models, in particular high-resolution and low-resolution models, is widely discussed in the literature [15]. The focus of these works is on the connection between the strategic planning with detailed analysis. Aggregation and disaggregation are techniques that facilitate interactions at the same level of interactions. The paper [16] illustrates common approach used in aggregation using Lanchester theory as a basis. Requirements for theoretically consistent aggregation, disaggregation, and partial aggregation have also been described. Consistency of aggregation and disaggregation in models of combat is a very desirable property.

The objective of this paper is to estimate the attrition rate coefficients from simulation approach using various statistical estimators to compare their efficiencies (that is, with minimal variance as far as possible); considering a typical scenario such as a "Meeting Engagement" of armour combat.

The simulation approach has also been known as the hierarchy-of-models approach or fitted-parameter-analytical-model approach, such as the attrition-calibration (ATCAL) methodology implemented in the U.S.A Army's CEM model [13,17]. The simulation approach for estimating attrition-rate coefficients in Lanchester-type models (described graphically in Figure 1[11]) consists of the following:

- collecting information through multiple run of Monte-Carlo simulation model,
- set of aggregated Lanchester equations,
- statistical estimation of attrition-rate coefficients,
- situation matching/extrapolation methodology, and
- solution of aggregated Lanchester equations.

[1] Institute for Systems Studies and Analyses, Defence Research and Development Organization, Metcalfe House, Delhi-110054, India.

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