Effects of the Cookie Cutter Function Shapes on Monte Carlo Simulations of Weapon Effectiveness

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***Abstract*—Several shapes of cookie cutter function have been used in weapon effectiveness analyses. Although it is perceived that different cookie cutter shapes would lead to different analysis results, little proof has been developed. This paper investigates whether different cookie cutter shapes produce different results of Monte Carlo simulations to determine the probability of damage on area targets. Four cookie cutter shapes, which are circle, ellipse, rectangle, and the actual shape of weapon lethal zone, were employed in a case study on multiple shots of artillery weapons against a uniform value target. The Monte Carlo simulations were carried out on different number of shots, targets, and weapon lethality data. Statistical analyses were performed and it was suggested that the difference between the results determined by different shapes of cookie cutter function was statistically significant but the effect of the shapes of cookie cutter function on the results was small.**

Keywords—damage function, cookie cutter, Monte Carlo simulation, weapon effectiveness

I. INTRODUCTION

When unguided artillery weapons, such as howitzers and MLRS (Multiple Launch Rocket Systems), are used against area targets, it is often necessary to analyze the probability of damaging or neutralizing the targets so the number of shots required for the mission can be determined and the operation can be planned efficiently. For simple target shapes, such as circle or rectangle, the calculation can be performed using various analytical methods, of which closed form solutions are available. These methods have been well described in many literatures such as [1-8] and recent comprehensive works on target coverage topics can be found in [9,10]. However, it can be seen in these literatures that the calculation can be complex or the closed form solutions do not exist when the target shapes are complicated or there are multiple targets to consider.

An alternative approach is to perform Monte Carlo simulations. This approach arguably has fewer limitations than using the closed form solutions. Not only the weapon lethality can be modeled more realistically, but also more complex target shapes and multiple targets can be conveniently included in the simulation. A Monte Carlo simulation to determine the probability of target damage normally comprises many runs. In each run, the weapon impact points are randomized in accordance with the weapon delivery accuracy and the probability of damage on the targets is evaluated. Then the simulation result can be estimated from the mean of the results in all runs. The number of runs in a Monte Carlo simulation is related to the confidence level and confidence interval of the results [11,12]. It may require up to several thousand runs in order to obtain reliable results.

Examples of recent works that involves performing Monte Carlo simulation to determine the probability of damaging a target are Anderson [13] and Prabhakar et al. [14]. Anderson [13] compared the results of the Monte Carlo simulations to the results determined by JMEM (Joint Munitions Effectiveness Manuals) method, which is a standardized methodology developed by JTCG/ME (Joint Technical Coordinating Group for Munitions Effectiveness) [15]. In Prabhakar [14], a Monte Carlo method is employed in a damage assessment software package for various weapon and target types.

In both analytical methods or Monte Carlo methods, damage functions are employed to describe how a weapon inflicts damage upon the targets. Several damage functions have been defined and the characteristics of these functions have been studied and compared in several research works [16-18]. Among the most popular damage functions is the cookie cutter function. The cookie cutter function assumes that the fraction of a target that lies inside the lethal area or a "cookie cutter" is completely destroyed. On the other hand, the fraction of a target that lies outside is left unharmed. Shapes of the cookie cutter function often used include circle, rectangle, and ellipse. These basic shapes are simplified from the actual shapes of the weapon lethal zone, which are normally determined by experiments or numerical simulations. Although the area of the lethal zone is preserved, using different cookie cutter shapes in the Monte Carlo simulations could cause difference in the results.

The objective of this paper is to compare the results of Monte Carlo simulations that utilizes different shapes of cookie cutter function to determine the probability of damage on an area target. A case study on multiple shots of artillery weapons against a uniform value target was carried out. Three basic shapes of cookie cutter function, which are circular, rectangular, and elliptical, and the shape of weapon lethal zone were employed in the Monte Carlo simulations to determine the probability of target damage. Statistical analyses were carried out to determine whether there was any difference between the simulation results determined by different shapes of cookie cutter function.

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