Model and Simulation of Artillery Kill Probability to Sea Targets

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ABSTRACT

It is an important military problem for artillery to fire at sea targets. To determine the damage probability of artillery is the premise for commanders to organize operations. In this paper, we distinguish single target and multi-target and establish the shooting model of island and reef Garrison Artillery at sea. For single target, the hit probability is used to evaluate the firing effectiveness of cluster target, and the average number of damaged targets is used as the evaluation index. This paper analyzes the first, second and third groups of errors that affect the hit probability, and calculates the hit probability by using Gauss Hermite method; it uses multi scale area shooting method for cluster targets, and gives the expression of determining scale number and firepower coverage area. The simulation results of single target and multi-target are respectively simulated and calculated by Matlab tool. The simulation results have promotion and reference value, It can provide a strong theoretical support for the commander to command the troops to fire at sea single target and cluster target.

KEYWORDS
Hit Probability, Error analysis, Kill Probability, Single Target, Multiple Targets.

INTRODUCTION

The main targets of offshore defense of islands and reefs are the formation of light offshore combat ships and landing boats, as well as other sea targets that enter the range of artillery fire. The fundamental problem of firing effectiveness of island and reef Garrison Artillery in sea combat is to solve the problem of projectile and target meeting. When the projectile hits the target and makes the target achieve certain damage accumulation, the target will be destroyed. The indexes to measure the shooting effectiveness include hit probability, damage probability and average number of damaged targets. For a single target, usually several guns, the hit probability can be used as the shooting effectiveness index. For multi-target or cluster targets, the average number of damaged targets is used as the shooting effectiveness index.

ANALYSIS OF SINGLE TARGET SHOOTING EFFECTIVENESS

The first, second and third groups of errors are the main factors that affect the
problem of artillery hit, and these three groups of errors are normal distribution functions with expectation of 0. According to the above model, there are three groups of errors at the same time. The total probability $P_{LM}$ of launching s-rounds is as follows:

$$P_{LM} = 1 - \sum_{t=0}^{m-1} \frac{S!}{(S-t)!} \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \varphi_{II}(x, z) \left[ \int_{-\infty}^{+\infty} \varphi_{III}(x, z) \left[ \int_{-\infty}^{+\infty} \varphi_{II}(x, z) \cdot p \left( x, x_{III}, z_{III}, z_{III} \right) \right] \cdot dx \cdot dz \cdot dx_{III} \cdot dz_{III} \right] \cdot dx \cdot dz$$

(1)

Among them

$$\varphi_{II}(x, z) = \frac{1}{2\pi\sigma_{II}\sigma_{II}} \exp \left[ -\frac{1}{2} \left( \frac{x^2}{\sigma_{II}^2} + \frac{z^2}{\sigma_{II}^2} \right) \right]$$

(2)

$$\varphi_{III}(x, z) = \frac{1}{2\pi\sigma_{III}\sigma_{III}} \exp \left[ -\frac{1}{2} \left( \frac{x^2}{\sigma_{III}^2} + \frac{z^2}{\sigma_{III}^2} \right) \right]$$

(3)

$$p \left( x, x_{III}, z_{III}, z_{III} \right) = \left[ \Phi \left( \frac{x_{II} + x_{III} + \frac{l_u}{2}}{\sigma_{II}} \right) - \Phi \left( \frac{x_{II} + x_{III} - \frac{l_u}{2}}{\sigma_{II}} \right) \right] \cdot \left[ \Phi \left( \frac{z_{II} + z_{III} + \frac{l_u}{2}}{\sigma_{II}} \right) - \Phi \left( \frac{z_{II} + z_{III} - \frac{l_u}{2}}{\sigma_{II}} \right) \right]$$

(4)

When $t = 0$, it means that the full probability $P_{LI}$ of launching s-shot and hitting at least one shot is as follows:

$$P_{LI} = 1 - \int_{-\infty}^{+\infty} \int_{-\infty}^{+\infty} \varphi_{II}(x, z) \left[ \int_{-\infty}^{+\infty} \varphi_{III}(x, z) \left[ \int_{-\infty}^{+\infty} \varphi_{II}(x, z) \cdot \left[ 1 - p \left( x, x_{III}, z_{III}, z_{III} \right) \right] \right] \cdot dx_{III} \cdot dz_{III} \right] \cdot dx \cdot dz$$

(5)

ANALYSIS ON THE SHOOTING EFFECTIVENESS OF GROUP TARGETS

In order to kill the cluster target, the following two conditions must be met simultaneously: one is that the cluster target is covered by the projectile dispersion area; the other is that the cluster target is damaged in the area covered by the gun. Assuming that the area of the fire shell area covering the cluster target is, then the number of targets in the area is:

$$u' = u \cdot \frac{\Gamma}{\Omega_m}, (0 \leq u' \leq u)$$

(6)

In general, the area of each small target in the cluster is far less than the area covered by artillery fire, that is, according to the important limit theorem.
Then the total damage expectation is:

$$E_K \approx \left[1 - \exp\left(-S\frac{l_l \cdot f_l}{\Omega \omega}\right)\right]u \frac{\Gamma}{\Omega_m} \quad (8)$$

The target fire coverage area is the depth of the area and the front width of the area

$$R_d = 2L_d\left[2\Phi\left(\frac{L_d + F_d}{\sigma_d}\right) - 1\right] + 2(L_d + F_d), \quad \Phi\left(\frac{L_d + F_d}{\sigma_d}\right) - \Phi\left(\frac{F_d - L_d}{\sigma_d}\right) + 2\sigma_d \Phi\left(\frac{F_d + L_d}{\sigma_d}\right) - \Phi\left(\frac{F_d - L_d}{\sigma_d}\right) \quad (9)$$

$$R_f = 2L_f\left[2\Phi\left(\frac{L_f + F_f}{\sigma_f}\right) - 1\right] + 2(L_f + F_f), \quad \Phi\left(\frac{L_f + F_f}{\sigma_f}\right) - \Phi\left(\frac{F_f - L_f}{\sigma_f}\right) + 2\sigma_f \Phi\left(\frac{F_f + L_f}{\sigma_f}\right) - \Phi\left(\frac{F_f - L_f}{\sigma_f}\right) \quad (10)$$

By substituting equations 26 and 27 into 25, we can get the following results:

$$E_{damage} \approx u \left[1 - \exp\left(-S\frac{l_l \cdot f_l}{\Omega \omega}\right)\right] \left\{ \begin{array}{l} 2\Phi\left(\frac{L_d + F_d}{\sigma_d}\right) - 1 + 1 + \frac{F_d}{L_d} \Phi\left(\frac{L_d + F_d}{\sigma_d}\right) - \Phi\left(\frac{F_d - L_d}{\sigma_d}\right) + \frac{\sigma_d}{L_d} \Phi\left(\frac{F_d + L_d}{\sigma_d}\right) - \Phi\left(\frac{F_d - L_d}{\sigma_d}\right) \\
2\Phi\left(\frac{L_f + F_f}{\sigma_f}\right) - 1 + 1 + \frac{F_f}{L_f} \Phi\left(\frac{L_f + F_f}{\sigma_f}\right) - \Phi\left(\frac{F_f - L_f}{\sigma_f}\right) + \frac{\sigma_f}{L_f} \Phi\left(\frac{F_f + L_f}{\sigma_f}\right) - \Phi\left(\frac{F_f - L_f}{\sigma_f}\right) \end{array} \right\} \quad (11)$$

It can be seen that the expected number of damage is a function related to the number of targets, the hit area of small targets, the number of projectiles launched, the distribution area of artillery fire, the distribution area of targets, the average number of bullets that must hit the target, and the mean square deviation of the error of the elements. The average damage rate is as follows:

$$P_{average} = \frac{E_{damage}}{u} \times 100\% \quad (12)$$
SIMULATION CONDITIONS

The kill probability of gun is related to many factors, such as shooting distance \((d_p)\), firing number \((S)\), target course \((Q_n)\), target route angle \((Q)\), target area \((\Omega_m)\) etc. The simulation conditions are shown in the table:

| TABLE I. SIMULATION CONDITIONS(I). |  |
|---|---|---|---|---|
| \(d_p\) (m) | S1 (single target) | \(\Omega_m\) \((m^2)\) | \(Q_n\) (°) | \(Q\) (°) |
| 1000~15000 | 1~8 | 26.1×15.6 | 0~\(\pi\) | 0~\(\pi/2\) |

| TABLE II. SIMULATION CONDITIONS(II). |  |
|---|---|---|---|---|
| \(d_p\) (m) | S2 (integrated arget) | \(\Omega_m\) \((m^2)\) | \(Q_n\) (°) | \(Q\) (°) |
| 1000~15000 | 1~5 | 200×300 | 0~\(\pi\) | 0~\(\pi/2\) |

SIMULATION RESULTS OF SINGLE TARGET SHOOTING

Use Matlab tool to simulate the impact of the number of hit, target course and target route angle on the hit probability:

![Simulated picture between multiple hit and hit probability.](image.png)

Figure 1. Simulated picture between multiple hit and hit probability.
SIMULATION RESULTS OF SHOOTING AT INTEGRATED TARGET

Use Matlab tool to simulate the impact of the number of projectiles and target course on the kill probability:

Figure 2. Simulated picture between course and angle of target and hit probability.

Figure 3. Simulated picture between the number of missiles and average damage probability.
CONCLUSION

A. For single target shooting, with the same firing distance, the more consecutive shots, the higher the hit probability. When the number of shots exceeds 6, the hit probability increases slowly. Therefore, a good shooting effect can be achieved by shooting 6 shots at a time.

B. For cluster targets, with the same firing distance, the more consecutive shots, the higher the hit probability. The hit probability increases slowly when the number of rounds exceeds 5.

C. When the target heading angle approaches 90° from 180° the hit probability decreases gradually. When the target heading angle decreases from 90° to 0°, the hit probability increases. When the target heading angle is 90°, the hit probability is the minimum point.

D. For cluster targets, the larger the heading angle is, the smaller the average damage probability is, and the smaller the heading angle is, the higher the average damage probability is.

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