Simulation and Evaluation Of Combat
Effectiveness Analysis Of Remote Control
Missiles In Net-Centric-Warfare

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ABSTRACT
War happens between two military forces for exhibiting their defensive power, strength and to protect natural resources like oil, petroleum products, gold, diamonds, precious mine & core. Defensive power is defined in terms of type of weapons, ammunitions, lethality power and tactical technology available with the military force. Missile is one of the weapons of military application which is used for survival of assets and engagement of target. A combat effectiveness of certain type of missile is done. A mathematical model with 6DOF of movements is established to describe the maneuverability of missile according to the targets position. For finding all possible movements of target Monte Carlo method has been used. Effectiveness indices such as hit probability and kill probability will be done and several factors influencing the precision of hitting will be analyzed. In this paper missile – target movement concept has been defined and will be implemented in future work.

Keywords: Angular momentum, Aerodynamic forces, Box-Muller transforms, Monte Carlo method, Simulation

Abbreviations: 6DOF-Six Degree Of Freedom

1.INTRODUCTION
In early days sticks and stones were used as weapons for wars. Then in next era elephants and horses were supporting them. Along with technology advances, computers and high technological concepts were introduced for weapon applications. In this paper high technology weapon as missile is considered.

Launching missile every time, analyzing its effect on target is economically, logistically, timely unaffordable. Therefore simulation model has been built up which is nothing but prototyping of real time scenarios.

Initially it is required to find & decide proper launch angle w.r.t. Missile’s launch position, target position and missile parameters so that missile hits the target & totally engages it. Whenever missile is launched, corresponding launch angle & distance between target & missile is maintained in a Look-up table. As and when required, look-up-table can be referred in future. Once missile is launched, it is obvious that target will move so as to survive itself and achieve the goal to hit the desired asset. At the same time, it is mandatory to track target by sensors and maneuver missile accordingly, for which 6DOF model has been used and for finding corresponding target movements /positions Monte Carlo method has been used.

Certain influencing factors come into account while maneuvering of missile, such as sudden change in atmospheric conditions, random wind, smoke generation by target etc. Those factors affect/reduce the hitting & killing probability of target. Analysis of hit & kill probability will be carried out to estimate number of missiles required to engage a particular target.

1.1. LITERATURE SURVEY
Ivan et al [1] describes an intelligent system for intercepting moving objects. He has considered the example of air hockey. Vision system, prediction decision system & servo pneumatics system have been developed in his work. The Straight Line movement estimation method has been used by him to estimate the position where the object will arrive, so that it will be intercepted. The results of this paper shows that a developed system is capable of intercepting moving objects with the speed less than 1.2 m/s, with sensing range 1.4m.Yang Fang et al [2] has found out hit probability and kill probability and necessary amount of missiles are obtained using Monte Carlo method. Pawat et al [3] has developed approach for generating firing table for Artillery projectile using iterative search and 6DOF trajectory mode. Rajesh et al [4] has generated random numbers using Monte-Carlo and Box Muller method to simulate random positions of foot prints. Rajesh et al [5] has carried out analysis for effect of metrological factors on trajectory such as effect of wind, density in his study.
2. PROBLEM DEFINITION:
Aim of our paper is to engage moving/stationary target by launching missiles at particular launch angle. Initial launch angle is predicted by using 6DOF [3] with respect to launch position, target position, aerodynamic condition and atmospheric conditions [5]. Launch position is location of missile launcher. Target position is co-ordinates of designated targets’ centre. Aerodynamic and atmospheric conditions are force parameters acting on missile. Those forces affect on missile trajectory.
System dynamics of missile is defined by Newton’s 2\textsuperscript{nd} law which says that rate of change of momentum is proportional to applied force as expressed in equation (1).

\[ \text{Applied Force} = \text{Rate of change of momentum} \quad (1) \]

Missile is launched with high thrust which generates a reaction on missile movement along line of fire in opposite direction of thrust i.e. Newton’s 3\textsuperscript{rd} law, equation (2).

\[ \text{Action} = \text{reaction} \quad (2) \]

Using Newton’s 2\textsuperscript{nd} law, acceleration at each time interval along X,Y,Z has been calculated and using Runge-Kutta method, velocity and position are calculated. After each time interval the target position is sensed by remote sensor/homing device and corrected futuristic launch angle is predicted using 6DOF. This process is executed iteratively till missiles reaches in the neighborhood of target where neighborhood is nothing but the assumed distance between missile and target (say) as 15m to 20m. Whenever missile is within vicinity of target then fuse in warhead gets initiated and sub-munition or bomblets gets detached from the warhead with the missiles velocity and hits the target. However, most of times around 20\% to 30\% of sub-munition or bomblets hits the target due to the orientation of missile and orientation of target. If the orientation of missile and target is proper i.e. they are almost in same trajectory line, then more than 50\%-60\% sub-munition or bomblets may hit the target. However target is also moving randomly with certain velocity, then missing of target is also considered in the problem.

Missing of target will happen, if the missiles velocity and energy gets reduced such that missile is incapable to reach near the target. In this situation, the next missile will be launched immediately and it follows the trajectory to reach near the target as per first definition. Sometimes ‘n’ number of missiles may be required to fire for engaging target to reduce its effectiveness and transform it into incapacitate target. In this problem, 6DOF model has been used for missile maneuverability and random number generation using Monte Carlo simulation for targets maneuverability.

Sometimes there might be multiple targets in air and on ground to be engaged, in these situation missiles, rockets and other weapons will be deployed. But to study all those combinations is not scope of our problem. We are defining a problem for missile engaging single target and this approach can be generalized for multiple targets and multiple weapons.

Hit probability and kill probability is also defined. This probability is defined for net centric warfare application where, sensors gives position of target at each time interval, information processing grid predicts futuristic position of target and shooter explodes sub-munition or bomblets near the target.

3. MATHEMATICAL MODEL:
Mathematical model is the representation of system dynamics.

3.1 6DOF model: 6DOF mathematical model has been used for missile dynamics. There are 3 Translational linear velocity components (u, v, w) and 3 rotational angular velocity components (p, q, r). Mathematical model equation can be defined as :

\[
\begin{align*}
\frac{m (du)}{dt} &= \Sigma F + mg \quad (3) \\
\frac{m (dv)}{dt} &= \Sigma M \\
\frac{m (dw)}{dt} &= \Sigma M
\end{align*}
\]

Where m - mass of the missile, 
V - velocity vector, \( \Sigma F \) - vector sum of all aerodynamic forces 
g - acceleration due to gravity 
H - total vector angular momentum of missile 
\( \Sigma M \) - vector sum of all aerodynamics moments
Using numerical integration Runge-Kutta method, change in translational velocity (Mdu, Mdv, Mdw), rotational velocity (Mdp, Mdq, Mdr), translational position (Mdx, Mdy, Mdz) and rotational position (Mx, My, Mz) of missile are estimated at each time interval ‘dt’.

Using above change in velocity and position at time interval ‘dt’, new velocity and position are estimated as:

\[
\begin{align*}
M_u &= M_u + M_{du} \\
M_v &= M_v + M_{dv} \\
M_w &= M_w + M_{dw} \\
M_p &= M_p + M_{dp} \\
M_q &= M_q + M_{dq} \\
M_r &= M_r + M_{dr} \\
M_x &= M_x + M_{dx} \\
M_y &= M_y + M_{dy} \\
M_z &= M_z + M_{dz}
\end{align*}
\]

(4)

Where missile parameters are

- \((M_u, M_v, M_w)\) – Translational velocity
- \((M_p, M_q, M_r)\) – Rotational velocity
- \((M_x, M_y, M_z)\) – Translational position
- \((M_\phi, M_\theta, M_\psi)\) – Rotational position

Initial parameters of missile are

- \((M_u, M_v, M_w) = (900, 0, 0)\)
- \((M_p, M_q, M_r) = (0, 0, 0)\)
- \((M_x, M_y, M_z) = (0, 0, 0)\)
- \((M_\phi, M_\theta, M_\psi) = (0, 45, 0)\)

3.2 Monte-Carlo simulation: Monte-Carlo simulation technique has been used for simulating target trajectory. After every time interval ‘dt’ new target co-ordinate is generated with random translation ‘Tdx’, ‘Tdy’ (0m to 10m) and rotation ‘Tdz’ (0° to 360°). Uniformly distributed over [0,1] two random variables (R1, R2) are generated. Random variables are transformed using Box-Muller transformation [4] method into random variable \(X_1\) with \(N[m, \sigma]\) where mean (m) as 0 and standard deviation (\(\sigma\)) as 1.

\[
X_1 = (-2 \log R_1)^{0.5} \cos(2\pi R_2)
\]

\[
Tdx = X_1 \times 10
\]

Similarly \(Y_1\) and \(Z_1\) random variables are generated and are used for estimating \(Tdy\) and \(Tdz\)

\[
Tdy = Y_1 \times 10
\]

\[
Tdz = Z_1 \times 360
\]

Using above Tdx, Tdy and Tdz values, new Tx, Ty and Tz co-ordinate as new position of target is estimated after each time interval ‘dt’ using:
\[
\begin{align*}
Tx &= Tx + Tdx \\
Ty &= Ty + Tdy \\
Tz &= Tz + Tdz
\end{align*}
\]

Where initial values of \(Tx\), \(Ty\) and \(Tz\) are given by sensor when sensor sees the target.

In Fig-2, dotted sphere shows possible futuristic position \(Tdx\), \(Tdy\), \(Tdz\) of target in flight after time interval \(‘dt’\) using above defined mathematical model.

4. FUTURE WORK:
Simulation of above defined problem definition and mathematical model using Java. Effect of atmospheric conditions and external perturbations on Missile dynamics will be implemented. Analysis of hitting and killing probability and estimation of number of missiles required will be carried out using simulation.

5. CONCLUSION AND OBSERVATIONS:
This approach gives hitting of missile to a target with certain killing probability and it can be generalized to \(‘m’\) number of target and \(‘n’\) number of weapons in net centric warfare.

6. ACKNOWLEDGEMENTS
We express sincere thanks to Shri RJ Mukhedkar for his valuable inspiration and motivation towards the subject.

REFERENCES:

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