Temasek Defence Systems Institute

Exploring Characteristics of an Effective Mix of Precision and Volume Indirect Fire in Urban Operations using Agent-Based Simulation

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Objectives

As the world continues its rapid rise in urbanisation, the battlefield of the future will likely be urban. This thesis explores the use of Agent-Based Simulation (ABS) to develop an effective mix of artillery precision weapons (Excalibur [M982], and Precision Guided Kit [PGK]) and dumb munitions (M795 HE) in urban warfare. Two urban case studies in the 21st century are used as notional and realistic scenarios for modeling purposes. "Pythagoras" ABS which was developed by Northrop Grumman was used to develop the models for this thesis. Measures of Effectiveness (MOEs) for the munition mixes are (1) Force Exchange Ratio (FER), (2) Time to accomplish mission success, (3) Fratricide rates, (4) Collateral Damage, and (5) Artillery Effectiveness.

Research Ideas

1. Efficient Design of Experiments (DOEs): 'Nearly Orthogonal Latin Hypercube' (NOLH) which are computationally efficient and have space filling properties to prevent cofounding effects of multiple factors are used in the simulations. A total of 65,280 simulated battles were generated using High Performance Computing Cluster (HPCC).

2. Multi-Objectives Evolutionary Algorithms (MOEA): NPS-developed evolutionary algorithms known as "ARTeMIS" (Automated Red Teaming Multi-objective Innovation Seeker) which is a stochastic, heuristic-based search algorithm are used to search for best-performing solutions through iterations. A total of 30 iterations and 2480 alternatives are generated using the HPCC.

3. Pareto Optimal Frontier (POF): With multiple objectives such as MOEs & cost, the concept of 'Pareto dominance' is used to evaluate overall performance. POF consists of decision points where it is impossible to improve either objective without making a trade off (worsening) another.

Results

For scenario 1, using DOEs with the objective of minimising all five scaled losses of the MOEs, a POF with 88 out of 451 munition allocations is identified. The mean proportion of M982 is 13.2 percent (95% CI [12.7, 13.8]) and the mean proportion of M1156 is 33.5 percent (95% CI of [31.0,36.0]).

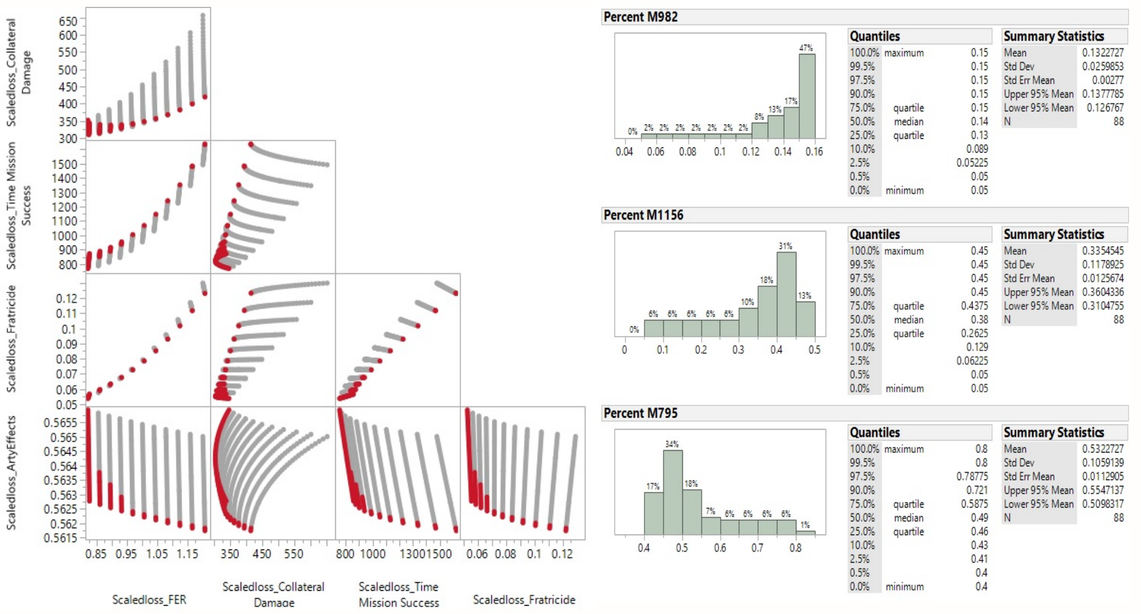

Figure 1 & 2: Scatterplot Matrix of the Scaled Loss MOEs & Histogram of the Pareto Optimal Frontier (POF)

For MOEA run on 3 objectives (1) minimise arty effectiveness, minimise total collateral and minimise cost, a POF with 104 out of 2480 alternatives is identified. The mean proportion of M982 is 11 percent (95% CI [10.2,11.8]) and mean proportion of M1156 is 11.6 percent (95% CI [10.5,12.8]).

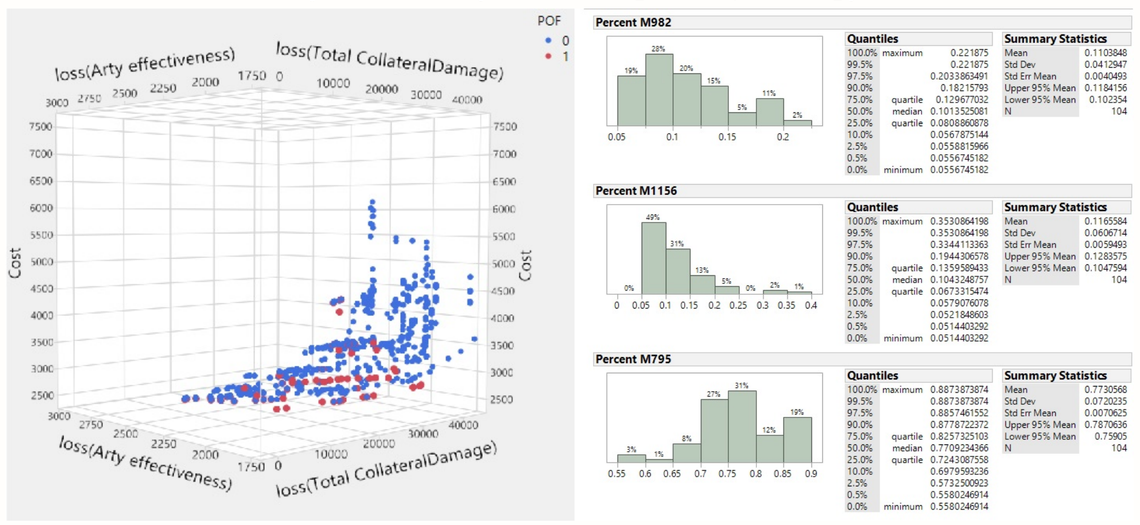

Figure 3 & 4: 3D Scatterplot of two Scaled Loss MOEs and Cost & Histogram of the Pareto Optimal Frontier (POF)

Benefits & Potential application

This study successfully demonstrates how the combination of efficient simulation techniques, with various data mining and optimization tools, can assist decision makers to make better decisions in a multi-objective problem. Ultimately, this helps to **win wars** with **minimal cost and lives being lost**.

Follow-up research

- Extension of research to include mortars, rocket artillery or even air assets for air-land integration fires (with classified data).
- Conduct further sensitivity analysis on the cost of munition allocation against operational effectiveness

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