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INVOKING "ARTEMIS" – THE MULTI-OBJECTIVE HUNT FOR DIVERSE AND ROBUST ALTERNATIVE SOLUTIONS

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ABSTRACT

The Automated Red Teaming Multiobjective Innovation Seeker (ARTeMIS) is a novel software application that implements a self-adaptive evolutionary algorithm that is designed to search for a diverse set of robust solutions in a multi-objective problem space. We present the details of our implementation and demonstrate its use on a simulation case study that considers two objectives.

1 INTRODUCTION

An evolutionary algorithm (EA) is a heuristic, stochastic algorithm that conducts a search over a large possible space of alternatives, usually used to seek a "best" candidate to a problem. The algorithm is considered evolutionary because it is inspired by Charles Darwin's theory of evolution and the principle of "survival of the fittest" natural selection. We name our algorithm after Artemis, the mythological Greek goddess of hunting. We choose to include the term "Red Teaming" in the name of the algorithm because we sometimes use an EA in our "Blue vs. Red" military domain to find good ways for an opposing Red Team to challenge or break a given Blue Team plan. However, the algorithm can be used to seek solutions to any problem, without regard to a preconceived Red or Blue side.

The major canonical EA approaches are: Evolution Strategies (ES), Evolutionary Programming (EP), and Genetic Algorithms (GA). Our algorithm most closely aligns with the ES methodology, specifically, the $(\mu + \lambda)$ model, in which μ parents are selected at each stage of the algorithm to produce λ children. ARTeMIS achieves self-adaptivity by adopting Schwefel's famous "1:5 rule" to determine how to balance exploration and exploitation by increasing or decreasing the mutation parameter σ (Schwefel 1975).

ARTeMIS takes the ES methodology in a new direction, by seeking a set of diverse robust solutions and considering multiple objectives. Robust means resilient to unanticipated and uncontrollable changes in the problem (Sanchez 2000). We seek a set of diverse solutions, rather than a single "best," in order to allow a decision maker to apply preferences or some other measure to make a final decision. We consider multiple objectives to allow for the evaluation of tradeoffs when it is not possible to simultaneously achieve a high score on all objectives with a single alternative solution. Additionally, we consider previous work, specifically the Strength Pareto Evolutionary Algorithm (Zitzler and Thiele 1999) and the Elitist Non-Dominated Sorting Genetic Algorithm (Deb 2001), as both of these algorithms apply an EA to problems with multiple objectives.

2 MILITARY APPLICATIONS

The testbed for our algorithm was a simulation scenario that we developed for the Marine Corps Combat Development Command Operations Analysis Division. The simulation captures the problem of finding Red mobile missile-launcher teams that present a threat to a shipping convoy transiting a strait. The decision

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variables represent Unmanned Aerial Vehicle (UAV) characteristics and employment, for example, the number of UAVs, UAV speed and sensor characteristics, as well as the length of time from contact discovery to contact prosecution. To simplify the visual presentation of results, we focus on two objectives, total (notional) cost and a quadratic robust loss function applied to the number of Reds captured. Less is better for both objectives. In Figure 1 we display the movement of the Pareto frontier over 200 iterations.

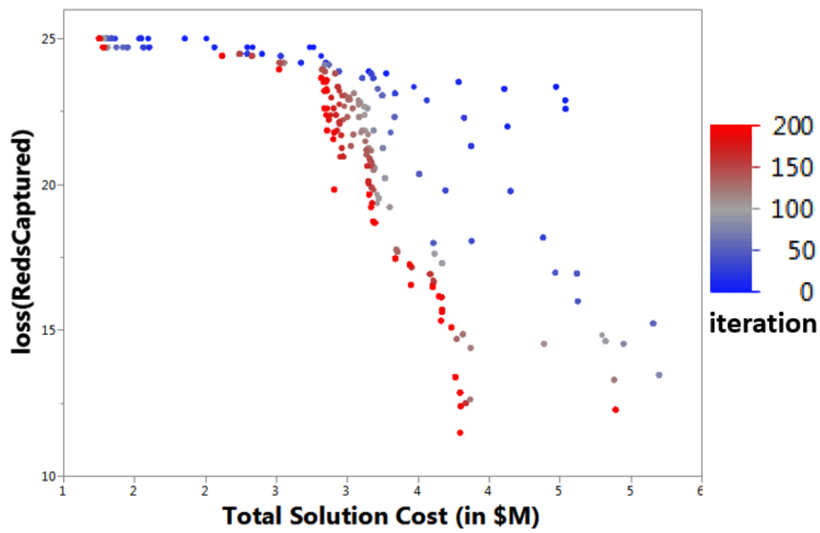

Figure 1: Illustration of the Evolution of the Pareto Frontier Over Time.

For this run, the final Pareto frontier consisted of 26 alternative solutions, from which a decision maker could choose given personal preferences or a different metric. Given the researchers' background in the field of design of experiments (see http://harvest.nps.edu), we also present our ideas on future work such as complementing the use of an EA with the techniques of designed experiments.

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