2019-12

Testing Multiple Credit/Blame Assignment Methods for Learning

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NPS NRP Executive Summary
Report Date: 12/18/19 | Project Number: NPS-19-N239-A
Naval Postgraduate School, Graduate School of Operational and Information Sciences

NAVAL RESEARCH PROGRAM
NAVAL POSTGRADUATE SCHOOL

MONTEREY, CALIFORNIA

TESTING MULTIPLE CREDIT/BLAME ASSIGNMENT METHODS FOR LEARNING OF MILITARY MISSION PLANNING

Period of Performance: 11/01/2018-11/30/2019

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Prepared for:
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EXECUTIVE SUMMARY

Project Summary
Technological surprise is an important concern of U.S. military organizations in a world in which the U.S. no longer has an advantage in many technologies. Technological surprise can be a new weapon, tactic, or strategy. Science and engineering can advance differently in other countries and result in surprises that provide an asymmetric advantage to an adversary. This work used the example of novelty in military vehicles, and we studied evolutionary algorithms to construct novel vehicles. Evolutionary algorithms model biological evolution and mimic the random mutations and crosses in populations, using a measure of "fitness" to determine the survivability of a particular offspring. For vehicles, fitness can be calculated from four factors: effectiveness, novelty, frequency, and cost, where the first two increase fitness and the second two decrease it. Effectiveness was based on measures such as weight, maneuverability, potential speed, material out of which it is constructed, and the degree to which it can occur in swarms. Novelty was based on dissimilarity to the most-similar known vehicle. Frequency was based on the number of similar vehicles likely to be encountered today. Cost was based on the material, size, and power. Data sources used in this study were a broad range of material on technological surprise. We also conducted some experiments with a simple program. Our experiments showed a number of surprising results that would provide decision-makers with challenges. We were also tasked with exploring the notion of surprise in the Libratus poker-playing program, and we concluded it had some, but not much military applicability.

Keywords: *technological surprise, evolutionary algorithms, vehicles, military, unknown unknowns, fitness, mutation, crossing, Libratus*

Background
Evolutionary algorithms are a form of machine learning, which is an important subarea of artificial intelligence in computer science. They can be used to do planning. They are a form of unsupervised learning, which means they do not use training examples but instead use feedback in the form of a fitness function, which ranks alternative solutions. In these operations, candidates are repeatedly "mutated" and "crossed" to produce new items, where mutations produce small variations on items and crosses combine properties of two items to get a new item. Evolutionary algorithms are intended to find novel and surprising solutions to problems, so they would seem a good way to anticipate technological surprise.

Findings and Conclusions
This work was designed to aid strategic planners. It studied the feasibility of a software tool to better anticipate technological military surprises, and in particular, to anticipate "unknown unknowns" that represent novelty which could cause asymmetric advantages for an adversary. N2/N6 is concerned with using information technology to address Navy needs, and this could provide them with a software tool for an important part of the Navy mission.

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Some of our demonstration experiments showed that evolutionary algorithms were feasible and effective in find plausible surprising military vehicles. Our results also indicated that these algorithms were not difficult to implement and customize for particular military threats. It showed their results could be easy to understand. Therefore, our hypotheses about how they could be effective were confirmed. However, as we have only studied the examples of military vehicles malicious software, and we cannot guarantee equally good results with other military technological surprises.

We were also tasked by the sponsor to investigate the Libratus artificial intelligence-based poker-playing program what lessons it provided for military strategy, since it has generated surprises to help beat professional poker players. We discovered that much of the software's impact was due to learning overnight from game play the previous day and this rarely has a counterpart in military strategy. Some of its impact was due to a decision-theory technique called "regret minimization" which better models human decision-making, and this is worth investigating further though its effects were not dramatic.

Data sources used in this study were a broad range of readings of relevant material analyzing the problem of technological surprises and how they can be better anticipated. We also constructed a simple program to generate surprises and experimented varying its parameters to see how they affected success. Student Eric Skalnes developed the first version of the program. There was an optimum number of parameters to vary, an excess of which slowed progress in finding surprises. An important parameter in our experiments was the size of the starting population of random items, since having it too small greatly impeded subsequent discoveries in these experiments.

Recommendations for Further Research

The approach using evolutionary algorithms appears promising, and could be applied to other military challenges such as anticipating new sensors, new weapons, new tactics during combat including new cyberattacks.