Project 4: Enhancing Decision Making Emulating Human Reasoning

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Project Summary

This research topic is inspired by one of the **NAE (National Academy of Engineering) Grand Challenges** for engineering, namely, **"Reverse-Engineer of the Brain."** As engineering solutions become more large-scale and complex, the desire is for machines to emulate a human's ability to adapt quickly and effectively. It is anticipated that the area of autonomy and control is a major research area for all unmanned systems, whether military, commercial, or academic in origin. Furthermore, adaptability and learning from past experience are still at early stages of capability. Intelligent systems technologies are enabling air and space missions to exhibit an increased level of autonomy, to be more adaptable, to learn, and to have improved performance. Within the framework of this REU program, we will utilize heuristics, based on human intuition and using intelligent systems technologies such as fuzzy logic and genetic algorithms, to develop new and unique approaches to large-scale combinatorial optimization problems.

A sub-class of very famous problems is referred to as the traveling salesman problem (**TSP**) which involves finding the shortest path (see **Figure 1**), and has applications in the several diverse areas such as aerospace, logistics, genetics, manufacturing, telecommunications, and neuroscience. The importance of the TSP is that it is representative of a larger class of problems known as *combinatorial optimization problems*. The TSP is an archetype of an NP-hard problem (i.e., scales exponentially with increase in number of cities). If one can find an efficient algorithm for the TSP, then efficient algorithms could be found for all other problems in NP. In complexity theory, the main question is whether or not there exists a polynomial time algorithm for an NP-hard

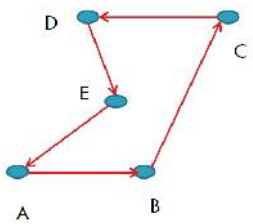

Figure 1: A 5 City TSP

problem.

The TSP may be described as follows: Given a set of **n** cities along with the distance between each pair of cities, the TSP requires us to visit each city exactly once and return to the starting point along the shortest path possible. For n cities, there are $[(n-1)!]/2$ possible solutions. An example for a 20 city problem is provided in **Figure 2**. For large values of n, the number of possible solutions is very high. Hence, it is challenging to find the exact solution for large problem sizes.

Figure 2: The TSP Solution for a 20-City Problem Having 6.1×10^{16} Permutations (from http:www.solver.com/solver-platform-sdk-source-code-examples)

Obtaining an optimal solution to high order TSPs takes time using the iterative computational approaches available in the state-of-the-art. In this effort we will investigate the applicability of a newly developed mix of fuzzy logic systems and genetic algorithms to provide a computationally efficient near optimal solution to a TSP. The quality and computational speed of the solution will be compared with that obtained using state-of-the-art genetic algorithm available on MATLAB Central. Monte Carlo simulations will be utilized to statistically validate the robustness of the proposed approach.

The ***goals*** of the research program are:

1. Develop a heuristic based approach to solving the TSP based on fuzzy logic;
2. Compare solution with state-of-the art techniques using available MATLAB genetic algorithms;
3. Validate using Monte Carlo Simulations.

Possible Ideas for Classroom Implementation

1. A possible **science unit** may involve the study of a ground robot built using LEGO Mindstorms visiting many geographically distributed locations and conducting tasks at each target. Heuristics will be utilized for obstacle avoidance path planning.
2. A possible Math unit will constitute the study of permutations and combinations possible in TSP class of problems and using logic, heuristics, and geometric considerations to find the minimum tours.
3. The faculty mentors and the Graduate Research Assistant will: (i) visit the teacher's class to assess the effectiveness of the lesson plan developed and to internalize lessons for improvement of the RET learning experience; and (ii) host the teacher's class to visit MOST AERO labs at UC to get an overview of the research applications explored by the graduate student research team working in the area of emulating human reasoning using fuzzy logic as well as bio-inspired approaches top large scale combinatorial optimization problems.

References

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