DESCRIPTION OF THE RESEARCH PROJECT FOR THE 2019 SUMMER RET SITE

Project: Bio-Inspired Optimization of the Multiple Traveling Salesman Problem

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Project Summary

This research topic is inspired by the NAE GC, "Reverse-Engineer the Brain" and linked to the ***big idea*** that intelligent system technologies are enabling air and space missions to exhibit an increased level of autonomy, adaptability, and performance [1]. The stated research ***challenge*** is to utilize human intuition and intelligent systems technologies, such as fuzzy logic and genetic algorithms, to develop new and unique approaches to large-scale combinatorial optimization problems [2]. We will be using the "Traveling Salesman Problem" as a benchmark for learning optimization. It has applications in several diverse areas such as aerospace, logistics, genetics, manufacturing, telecommunications, and neuroscience [3]. Recently, the UC's genetic fuzzy based AI approach was extended by Ernest et al. [4] as the first ever to successfully overcome a human pilot in an air-to-air combat simulation.

The TSP is defined in the following way: a traveling salesman has to visit a certain list of cities, whose locations are known, such that each city is visited exactly once, while minimizing the total cost of travel (see **Figure 1**). Cost is usually defined in terms of distance, time, or price, with fixed costs associated with travel between each pair of cities. Obtaining an optimal solution to high order TSPs takes time using the most advanced iterative computational approaches available [3]. The TSP is expanded in many practical applications to include "multiple salesman" (see **Figure 2**) which leads to the "Multiple Travelling Salesman Problem (MTSP)" [4]. The current research will develop algorithms to investigate both the TSP and MTSP.

Figure 1: 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.html

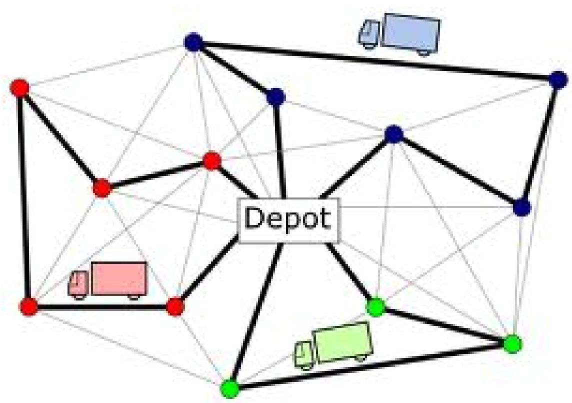

Figure 2: The Multiple TSP from:
http://www.rcasts.com/2010/11/any-r-packages-to-solve-vehicle-routing.html

The ***guiding questions*** to answer while addressing the research ***challenge*** are: 1) How can a newly developed interface of fuzzy logic and genetic algorithms [5] be enhanced to solve the MTSP? 2) How is a Monte Carlo Simulation used to design and test new and current algorithms? 3) Can hybrid algorithms be formed to further optimize the performance and/or accuracy? 4) How can the algorithms developed during this research be benchmarked with the current state-of-the art algorithms? The real-world applications linked to these ***guiding questions*** will be explored during our field trip to the UVA Masters Lab at UC's Victory Parkway campus. The tour will explain how the algorithms being developed in the current research can be uploaded to a UAV prior to a mission and then used to optimize the flight path. The teachers will then partake in a training program on how to fly UAVs.

Training Provided: Teachers will first learn about the merits of MTSP, the underlying computational challenges, operational constraints, and the current state-of-the art approaches. They will then be trained using the MATLAB software to develop basic computer programming skills. These skills with then be used to introduce Fuzzy logic and genetic algorithms, MATLAB toolboxes for engineering applications, and Monte Carlo simulations. The training skills will then be utilized to develop algorithms for optimizing the TSP and MTSP.

Multi-Copter Platforms at UC Including Package Delivery

Research Facilities: The research will be conducted at the UC's Most Aero Labs (http://most-aero.uc.edu/). The facility has 500 ft^2 dedicated for lab space housing six experiments from Quanser which involve a linear inverted pendulum, a linear flexible joint, a seesaw module, a two degree-of-freedom helicopter, a vibration control structure, and a Shake Table I-40. RET participants' research is computational in nature and will be conducted on desk-top computers in the lab. MOST-AERO LABS has 5 PCs and a workstation for computationally intensive research. The following software is available: MATLAB©/SIMULINK© and all relevant toolboxes; CIFER©– NASA Ames's State-of-the-art Nonlinear System Identification; and, CONDUIT© **-** NASA Ames's Feedback Control Design toolbox for non-linear dynamic models developed using CIFER©.

Research Timeline: The following tasks will be completed during this research project:

Week 1: Learn MATLAB coding commands, syntax, and programming algorithms based on sequential, conditional and repetition logic.

Week 2: Define and implement a TSP problem within MATLAB.

Week 3: Construct a 2-opt algorithm and a genetic algorithm to find an optimal solution for the TSP, and then compare results to known TSP solutions.

Week 4: Create a new hybrid algorithm which employs the strengths of both the 2-opt and genetic algorithms to optimize solutions to the TSP.

Week 5: Test each algorithm by solving the same TSPs with different algorithms, and then analyze the data to determine the performance of the developed algorithms.

Week 6: Implement a clustering algorithm to improve the performance of the developed algorithms and explore the MTSP.

Week 7: Finalize deliverables for the project including a final presentation, poster, final report, and summaries.

Ideas for Classroom Implementation: The MTSP offers a wide variety of classroom applications built around using optimization to minimize the impact of Design constraints. Optimization is directly linked to the Engineering Design Process (EDP) because many solutions are possible, and the computer algorithms the teachers develop can be used to "Identify Alternatives" and ultimately "Select the Optimal Solution." A classroom unit will constitute the study of permutations and combinations possible in MTSP class of problems and using logic, heuristics, and geometric considerations to find the minimum tours. An EDP activity could follow that utilizes ground robots for path planning with simulated communication constraints that directly use the genetic algorithms developed during the research project. The research team is willing to visit the teacher's class to assess the effectiveness of the unit plan developed and to internalize lessons for improvement of the RET learning experience.

Industrial Partner: Dr. Nicholas Ernest, President & CEO of Psibernetix Inc. in Cincinnati, Ohio has agree to directly interact with the team. The majority of his work has been in national defense, but at the same time he has extended the same capabilities to biomedical applications, sports training, scheduling/inventory optimization. He is willing to visit the teacher's class during the school year to discuss with their students about career applications.

References Cited

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