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Undergraduate Research Program

Project Name	Development and Implementation of Parallel Hyper-spherical Algorithms in GPUs and Quantum for Finding Large Scale Competitive Solutions for the Traveling Salesperson Problem
Campus & Location in Mexico	Monterrey
Faculty	Business
Research Area	Operations Research
Research Responsible	Federico Trigos
Description of the Project	TThe classic traveling-salesperson problem (TSP) consists of finding a minimum distance tour through a known number of cities returning to the initial city without visiting any city more than once. This problem in its quantitative form applies to many real life situations, such as: public urban transport, logistics and distribution of products, sequencing of products for manufacturing under setups, sequence of machining movements for machining parts in manufacturing, assembly of electronic circuits, warehousing, etc. It can be said that an important part of the efficiency of an organization, community and even country depends on obtaining efficient solutions to this classic problem. Unfortunately, the only way to ensure optimal solution for the n cities TSP involves reviewing (n-1) factorial solutions, which is literally impossible for most practical applications. This problem is classified as NP-Hard, so it is believed but it has not been proved that there is no algorithm that finds the optimal solution in efficient time. Even though TSP is a classical combinatorial problem with more than two hundred years of study by the international academic community, it is still alive and a very active line of research. In the literature there are two main methods of solution, the first uses the branch and bound method (with multiple versions) and the second involves the use of heuristics (efficient methods that do not seek the optimal but good solutions). One of the main causes of the outlying efficient optimal algorithms is that efficient modeling of the feasible region of this problem is unknown. The modeling approach to follow in this proposal is to profit from hyper-spherical heuristic based on the fact that all feasible solutions to the problem are in the convex hull of a hypersphere of radius sqrt(n). This idea has been submitted by Federico Trigos (Tecnologico de Monterrey, Mexico, and technical responsible for this â€œCiencia de Frontera 2019â€proposal), Aydin Nassehi (University of Bristol, UK) Javier Gonzalez (Arizona State University, USA) and Adrian Ramirez (Universidad Panamericana Mexico) to a Q1 journal in July 2020 and currently on review. In recent years, two technologies have started to be used in research to attempt solutions for problems with these characteristics: GPU-parallel computing and Quantum computing. Our approach is to use them both in our implementation efforts. Internationally the use of graphics processor (GPU) based parallel computing is one of the cutting-edge tools for implementing methods for speeding up compute-intensive or mathematically-intensive tasks by harnessing the power of GPUs for the parallelizable part of the computation. GPUs have a highly parallel structure that makes them more efficient than general-purpose central processing units (CPUs) for algorithms that process large blocks of data in parallel. GPU-parallel computing has become an important subject in the field of computer science and has proven to be critical when researching high performance solutions. Quantum computing technology is starting to be used in research to attempt solutions for problems that require high performance solutions. The theory of quantum computing brings together ideas from classical information theory, computer science, and quantum physics. It has led to some profound and exciting new insights in the solution of problems that were believed to be unable to be solved. The existence of commercial and broad available Quantum Computers is still beyond the abilities of current technology. However, an important milestone for this new revolutionary way of processing data is being done and the principles of quantum information physics can be tested on emerging devices available for researchers around the world. The purpose of this research proposal is to form a team that directly includes researchers from Tecnologico de Monterrey (Federico Trigos) and Universidad Panamericana (Adrian Ramirez and Javier Gonzalez), including collaborative researchers from the University of Bristol (UK, Dr. Aydin Nassehi) and Arizona State University (USA, High Performance Computing Initiative), to enhance Trigos and Nassehi' work to a large scale level using advanced mathematics (first year), high-performance GPU-parallel computing (second year), and Quantum computing (third year). Dr. Federico Trigos is an expert in simulation, math programming, business analytics and industrial and corporate statistics. Dr. Adrian Ramirez is an expert in simulation and optimization of manufacturing and service systems. And, Dr. Javier Gonzalez has extensive experience with high-performance computing (multi-processor, multi-core, and GPU-parallel), real-time data processing, and intelligent systems development. Dr. Aydin Nassehi is the Head of the Mechanical Engineering Department at the University of Bristol, he has extensive research in this area and he could give us access to facilities and human-power (faculties, graduate students, and postdoctoral) of his University for this project. ASU High Performance Computing Initiative could provide high performance and high throughput computing environments to support research data needs. We plan to solve the Waterloo TSP set including the largest benchmark problem (The worlds TSP with 1,904,711 cities)efficiently, and to compare the computer efficiency obtained from GPU-parallel and quantum computing adjusting the algorithms depending on the computer infrastructure.
Training Provided	Super computer usage and code writing, mathematical programming modeling and algorithms

Offered during:

SUMMER	WINTER	SEMESTER
X		X

Student

Tasks/Responsibilities	Research assistant
Required Language Proficiency	English
Required Skills and Abilities	Parallel GPU code writing, Operations research courses taken
Other Documents	1) Being at least in your 2nd year of bachelor 2) Accumulative grade point average (GPA) 2.5 3) Official Transcript 4) 2 letters of recommendation of faculty members 5) Resume 6) Letter of intention explaining the reason why you would like to participate in the research program