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Dr. Michael Owen

For many members of the university community, computers are simply tools with which we undertake our daily tasks – preparing lecture notes and presentations; composing, receiving and transmitting e-mail to our colleagues and students. However, for many of our colleagues, computers are more than just tools of the trade – they are the subject of as well as the tools for their scientific research.

In this issue of *Research Reporter*, Erin Kaipainen profiles the scientific research of two faculty members in Computer Science whose research is supported by the Natural Sciences and Engineering Research Council.

Dr. Beatrice Ombuki conducts research in the field of artificial intelligence (AI). By applying principles of biological evolution to computer engineering, Ombuki seeks ways to employ the capacity of computers to locate optimal solutions to problems that professionals in business and finance, geological sciences and medical sciences encounter in their research and professional practice. Moreover, the applications of her research will have applications to our daily lives.

Dr. Sheridan Houghten's scientific research seeks solutions to problems of data transmission through the use of error-correcting codes. Her research is at the interface of mathematics and computer science and has applications in the fields of computer graphics, economic planning, pharmaceutical testing, factory scheduling (e.g., industrial engineering), and, potentially, university class timetabling.

Drs. Houghten and Ombuki are women succeeding in research fields that are dominated by men. Along with other female scientists at Brock, such as Drs. Miriam Richards, Fiona Hunter and Maureen Reedyk, Houghten and Ombuki demonstrate how women serve as role models for young female students who may desire to study and succeed in the sciences, especially those which are often viewed as preserves for men.

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Dr. Betty Ombuki

Survival of the Fittest: Darwinian Evolution meets Computer Science

Artificial Intelligence (AI) is a concept that is often misunderstood. The popular belief is that AI consists of the development of computers that exceed the intellectual capacity of humans. While today's "thinking" machines are nowhere close to the stuff of science fiction, they are much more intelligent than robots of just a decade ago. However, as Dr. Beatrice Ombuki of the Department of Computer Science explains, Artificial Intelligence consists of two categories: generalized (often called strong) AI and narrow (weak) AI. Contrary to what many people think, not all aspects of Artificial Intelligence claim to be able to think on a level that is equal or greater to that of human intelligence. Claims of this nature belong to strong AI, whereas "weak AI simply states that some 'thinking-like' features can be added to computers to make them more powerful or useful tools." It is this latter form of AI that Ombuki employs to solve real-world problems by using artificial neural networks and genetic algorithms.

"Genetic Algorithms," she explains, "are a computer modeling of biological evolution in which the search for the ultimate solution to a specific problem begins with an initial set of solutions which then generate successive generations of better solutions." This particular branch of AI was inspired by living things that have evolved into more successful organisms in nature, with the main idea being, "the strongest solutions survive." Inspired by Darwinian evolution, genetic algorithms operate basically on biological methods of "crossover, mutation, and reproduction."

Genetic Algorithms (GA), which keeps a population of solutions of which some die and others reproduce and are carried on to the next generation, are employed by computer scientists like Ombuki to develop programs for solving "practical, combinatorial optimization problems."

Despite today's ever-increasing computing power, there are still many types of problems that are difficult to solve. An example is combinatorial optimization problems, which are still quite challenges to solve. The term, combinatorial optimization, is employed when a computational task involves combining a set of different entities in a specific manner and yet numerous possibilities exist. A real-life example of this type of problem can be found in the design of reliable network topologies where various configurations are possible or in transportation problems. An example is the dispatch of vehicles from a central depot (or multi-depots) to distribute goods to various stores in Ontario based on the number of vehicles dispatched, vehicle capacity,

store hours, and number of stores as some of the perimeters. Combinatorial optimization strives to configure these different parameters in a way that provides the optimal solution, which in this case, is finding the cheapest routes by minimizing the number of vehicles employed and reducing the total distance traveled while obeying store hours and not overloading the vehicles. However, many combinations exist, even for a seemingly small problem. Determining an optimal solution for these kinds of problems through enumeration of all possible combinations is computationally intractable, or it would take an infinite amount of time to reach, in which case, it is more desirable to choose a more general algorithm.

The Natural Sciences and Engineering Research Council (NSERC) is funding her research program, "Evolutionary Computation in Search and Optimization." Through this research, Ombuki hopes to contribute to "developing further insights into the design and application of genetic algorithms to provide suitable solutions for difficult combinatorial optimization problems." In particular, she is interested in providing good solutions for combinatorial optimization in the areas of vehicle routing and scheduling, flexible scheduling in manufacturing systems, and the design of reliable network topologies. Often, finding an optimal algorithm to solve such problems requires an exponential amount of time. Since this is a luxury programmers cannot afford, Ombuki is proposing the development of "approximate techniques based on evolutionary computation because such general algorithms can be applied to related areas in the initial stages of solving a problem." Through her research, Ombuki also hopes to gain a greater understanding of this area of Artificial Intelligence. "Some GAs," she explains, "have not produced the successful results of others." She hopes to discover exactly what it is that makes "some problems more suitable than others for GA application." Success with the application of GAs has been demonstrated "in such diverse fields as product design, layout problems, database query optimization, transportation problems, manufacturing scheduling, game playing and bioinformatics."

In recent years, it has been demonstrated that another nature inspired technique, "swarm intelligence" has been applied with success and is comparable to genetic algorithms in some aspects in solving various practical problems. Ombuki's student, Mario Ventresca (an honor student in Computer Science

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who did RA work with Ombuki during the summer) is working on developing an Ant Colony optimization technique that uses artificial ants to find good solutions to difficult combinatorial optimization problems. Ombuki/Ventresca want to compare the effectiveness of the ant system on some of the problems they have solved and then develop a more superior optimization technique that combines both genetic algorithm and ant system.

Artificial Intelligence is not limited to applications in Computer Science, Ombuki explains, as "it has been useful in Expert Systems, a branch of AI that has been successfully designed to provide practical solutions in fields such as geology, medicine and the financial sector." For example, Ombuki explains

that in the financial design making sector, "expert systems have been effective in providing assistance to banks, credit card companies, and mortgage companies to detect fraud and expedite financial transactions." Other applications of AI technology include language translation systems, robotics, and handwriting recognition systems.

While completing her graduate studies with the Department of Information Engineering at the University of Ryukyus in Japan, ninety per cent of Ombuki's peers were male. However, the gender disparity is characteristic of computer scientists as a whole as "only four per cent of full professors and ten per cent of assistant and associate professors in computer science are women." Ombuki is accustomed to working in a discipline that is predominantly male, but she remains worried about the gender imbalance

adding, "I have noted with concern the low registration of female students in our departments. In this area, I will be keen to assist in any way I can, to promote more female interest in computer science."

Generally, far more men study computer science than do women. However, as it is, Ombuki explains, "AI is still a relatively new field in computer science compared to other more established areas like software engineering." While the majority of computer scientists are men, Ombuki explains that, "in recent years, we have seen more and more female computer scientists who do work in Artificial Intelligence." ●

Article by Erin Kaipainen



Dr. Sheridan Houghten

At the Intersection of Mathematics and Computer Science

Sheridan Houghten, an Assistant Professor with the Department of Computer Science, has always enjoyed the problem solving aspects associated with her discipline. Her current research, "Combinatorial Searches and Algorithms," funded by the Natural Sciences and Engineering Research Council (NSERC), is allowing her to solve more programming problems in areas such as data transmission through the use of searches. In part, this research will assist in the discovery of new error-correcting codes. Houghten also works on the development of "efficient algorithms and programs for the use in combinatorial searches."

Houghten describes her work as the solving of mathematical problems through the use of computers. "Computers," she explains, "facilitate mathematical problem solving and increase efficiency. And," Houghten adds, "I have always been interested in research at the intersection of mathematics and computer science."

Through her research, Houghten hopes to find different mathematical objects, such as error-correcting codes, which, once generated, can be used for various purposes. A common example of where an error-correcting code is used is the compact disc, which relies on stored information to run programs or to play music. However, the data stored on a CD can become inaccessible if the CD becomes dirty or scratched. An error-correcting code is essentially a means, encoded in the pattern of the CD, to access damaged information. Similar errors can occur during the transmission of data through a phone line or

through satellite transmissions as a result of noise. "When using an error-correcting code," Houghten explains, "we store the data according to a specific pattern before transmitting it. After transmission, this pattern allows

us to determine in which bits such errors have occurred, and to correct the errors."

However, as Houghten explains, "error-correcting codes do not exist for all sets of parameters." Using an error-correcting code therefore means that a search must be executed in order to discover if such a code with specific parameters even exists, and if it does, the researcher must determine its structure.

One of the primary, long-term objectives of Houghten's research is to develop efficient algorithms for use in combinatorial searches, "in order to minimize the problems that arise out of the potentially huge size of search spaces."

Houghten, with the assistance of a student research assistant, Michael Letourneau, has already reached one of her research goals. Together, they have developed libraries of programs for use in combinatorial searches. Houghten hopes that the establishment of these libraries will facilitate and reduce the time needed for future searches because in the early stages of this type of research, "the techniques are often sufficiently general and existing algorithms may be deployed in similar searches." In the initial stages, "many combinatorial objects have enough similarity that one may use a generalized approach to solve at least part of the problem." Eventually, Houghten hopes to extend the library of programs in order to make them more applicable to the research of others. "The main goal," she explains, "is that the researcher would be able to try different possibilities at the early stage of the search and draw some conclusions in order to make strategic decisions about

how best to proceed."

Houghten's research is of particular importance to others working in the combinatorics community, but also to those involved in complex problem solving areas such as "factory scheduling, university class timetabling, computer graphics, economic planning and pharmaceutical testing." Houghten has also been looking a newer area of combinatorics in which "error-correcting codes go beyond the confines of present day computers and anticipate future developments," says Letourneau.

At present, computers use binary systems to store and transmit data in a series of 1s and 0s. Houghten has been focusing more attention on "ternary codes" which operate using 0s, 1s and 2s. Recently, Houghten and her team have given consideration to using their current search procedure to examine "quaternary codes." The drawback to quantum information transmission is that it is prone to errors but the benefit is that when paired with quantum cryptographic techniques, quantum information transmission "provides absolute security for transmitted information." Letourneau explains that this has enormous benefits for anyone who needs to ensure the security of information.

Houghten began her education in Mathematics as an undergraduate student at Concordia before she went on to complete her Master's and her Doctoral degrees in Computer Science, at Concordia. ●

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