Science & Technology

Geometry and the new computer revolution

by Charles B. Stevens

For more than two decades, the power of computors have been increased every year by about a factor of 10. This steady advance in computing power has almost been entirely due to improvements in computer hardware—smaller and faster circuits, etc. Now a 28-year-old Indian-born mathematician, Narendra Karmarkar, working at Bell Labs in Murray Hill, New Jersey has achieved a fundamental breakthrough in the science of computer programming which promises to vastly accelerate the evolution of computer capabilities.

While there has been significant coverage on this breaking development in the national press, these initial reports have not pointed out what leading experts have reported to this publication: Karmarkar's discovery will revolutionize defense capabilities, in particular President Reagan's Strategic Defense Initiative (SDI).

The area of computer programming in which Karmarkar has made his breakthrough is that of linear programming, the most utilized type of problem solving found in industry and defense computer applications. Until now solving linear programming problems depended upon the simplex method developed by Dr. George Dantzig of Stanford University. This method was restricted to a step-wise, algebraic counting procedure. Karmarkar's method consists of utilizing a non-algebraic, synthetic geometrical approach which generates a minimal path to the desired solution. In particular, Karmarkar uses a series of projective transformations and the invariance of the "cross-ratio" "to create a sequence of points which converges to the optimal solution."

Karmarkar's new method has already been shown to be 50 times faster than the existing algebraic simplex method in direct comparison runs. On larger problems, Karmarkar's method promises to be exponentially faster.

Linear programming and problem solving

Linear programming is the most general type of problem solving found in business, industry, and defense. For example, in running a factory or an airline, we would have numerous types of inputs which must be put together in the correct proportions to make the system perform smoothly and efficiently. Linear programming consists of combining these input variables with linear equations which represent their functional interrelationship to find an optimal operational configuration.

In the simplex method, the problem is represented as a solid whose corners represent potential solutions. Each of the corners is examined by the computer to find the optimal solution. This search process is restricted to traveling along the edges of the solid. Karmarkar has utilized projective geometric transformations to create an entirely new path through the interior of the solid to the optimal solution corner. The simplex method could in the worst case involve examining all of the corners. Geometrically, the number of corners is equal to 2^n, where n is the number of variables in the problem. That is, the number of computations needed to solve linear programming problems with the simplex method can grow exponentially with the number of variables involved. With the Karmarkar geometric method the number of calculations only grows in direct proportion to the number of variables involved.

Practical implications

Interviews with leading defense computer scientists strongly indicate that Karmarkar's breakthrough will revolutionize all areas of military technology and in particular, meet most of the computer needs of President Reagan's SDI program for developing beam-weapon defenses against offensive nuclear weapons. The key point emphasized by these specialists and by Karmarkar himself is that the breakthrough so speeds up computer problem-solving that it means that problems can be solved in real time. That is, the computer produces the solution before new data inputs are received. This will make radar, sonar, and various other target pointing, tracking, and acquisition systems much more self-reflexive and interactive.

Defense technologies

One leading expert reports that the breakthrough could revolutionize submarine detection. Long-range submarine detection is primarily based on the ability to simulate with a computer the ocean's interaction with sound waves. In this way, submarines can be detected over ranges of thousands of miles. But the computing time, even with the largest computers, takes several hours with present methods. One expert reports that Karmarkar's breakthrough promises to reduce this computer time by a factor of 100. Thus, the submarine could be detected within an area of several hundred square miles instead of that of 100,000 square miles. (Air dropped, local sonar detection would then pinpoint the exact location of the sub.)

In terms of missile defense, reducing computing time to real time will have the most dramatic impact. Take the existing Navy Aegis missile defense system for large carrier task force groups. Because existing computer systems are not fast enough to analyze and absorb all of the potential radar data that is actually received on a real time basis, the Aegis system consists of methods developed to minimize the amount of data that must be analyzed to find specific targets. All of the ship radars are interconnected by a single, integrated computing system and using radar sensors on the anti-missile missiles themselves minimizes the amount of radar/computing time that must be utilized to find a specific target. In this way the number of missiles that the task force could detect and destroy coming from any location was raised from a level of 6 missiles per second to about 100 missiles per second. The Karmarkar development promises to improve this capability by many orders of magnitude. The reason is that by going to real time, the more accurate narrow radar beams will be able to be directed at targets rather than having to be used in a general sweep mode as is currently the case due to slow computing times.

Specific beam weapon applications

- Pattern Recognition in Real Time: This means that friendly and enemy forces and decoys can be distinguished with the minimum amount of sensor data inputs, such as radar, infrared or visual image.
- Calculating Missile Trajectories: Present missile tracking capabilities are based upon either already guessing the general missile trajectory or utilizing a large amount of sensor capability to sweep large regions of space in order to keep the missile under observation. Real time computing will make the utilization of sensor systems far more efficient and thus permit the tracking and targeting of tens of thousands of missiles and warheads with minimal deployed sensor capabilities.
- Targeting and Automatic Pilots: Computational times currently limit the rate and accuracy of targeting. Making computation real time will immensely increase accuracy and the numbers of targets that can be intercepted during a given period of time. Automated pilots are currently not fully realizable because of the bottleneck in computing time. With real time computation true automated pilots will be feasible for the first time and this will greatly improve the effectiveness of all types of missile interception, whether it would be a missile or beam interception.

Near-term prospects

In an interview, Bell Laboratory spokesmen said that they are just about to release detailed data on comparison runs utilizing Karmarkar's discovery. They also indicated that large-scale application of this breakthrough will probably begin by the end of this year. In the meantime, the U.S. Defense Department will be holding a special seminar in February on this development and its implications for existing and future military capabilities.