CONNECTING THE DOTS

BY TOMMY NEWTON

SITTING AT HIS DESK, DR. MUSTAFA ATICI TAKES A PEN AND BEGINS DRAWING SHAPES ON A SHEET OF PAPER. FIRST HE DRAWS A SQUARE, THEN CONNECTS THE CORNERS WITH AN X AND ADDS A TRIANGLE SHAPE ON TOP. IT LOOKS LIKE A SIMPLE HOUSE A YOUNGSTER MIGHT DRAW — AND THE ORIGINAL PICTURE DOES APPEAR AS A GAME ON THE KIDS' MENU AT A BOWLING GREEN RESTAURANT.

"Now you're going to start at one point, and draw each line once. Can you cover all the lines? That was the question in the handout for kids," Dr. Atici said. "It looks like a simple question but this is nothing but a graph problem."

The game may look like connect the dots, but it's actually an example of graph theory. "It's amazing. Almost every problem can be made a graph problem," he said.

Dr. Atici, Associate Professor in the Department of Computer Science at WKU, asks his students to look at a graph problem that his father showed him as a middle school student in his native Turkey. The problem involves connecting three neighboring houses to three water wells. Each house must have a path to each well but the paths can't cross each other. "Is it possible to find such a path?" he asked.

Dr. Atici always offers to buy lunch for a student who can solve the problem. "But I know this cannot be done," he said. "This is undoable."

Mathematics wasn't Dr. Atici's best subject during his middle and high school years. But at the Ege University, Izmir, he became a top math student as he focused on applied math over pure math.

At the Turkish university, his adviser offered a course on graph theory and had a copy of a book by Frank Harary, one of the world's leading graph theorists. "It was the kind of math we had never seen before," Dr. Atici said. "Simple, game-type math. Not too-complicated proofs. You got to draw interesting pictures. That's how I got started."

After receiving his bachelor's degree in 1986, Dr. Atici attended the University of Nebraska, where he received master's degrees in math (1991) and computer science (1994) and his doctorate in computer science and engineering (1996).

In graph theory, the graph is a collection of dots (or vertices) that may or may not be connected to other dots by lines (or edges). Graph theory has numerous applications beyond math and computer science, Dr. Atici said. It can be used in research projects in areas like engineering, computer science, or any applied science, and in community planning to build highway systems or utility infrastructure.

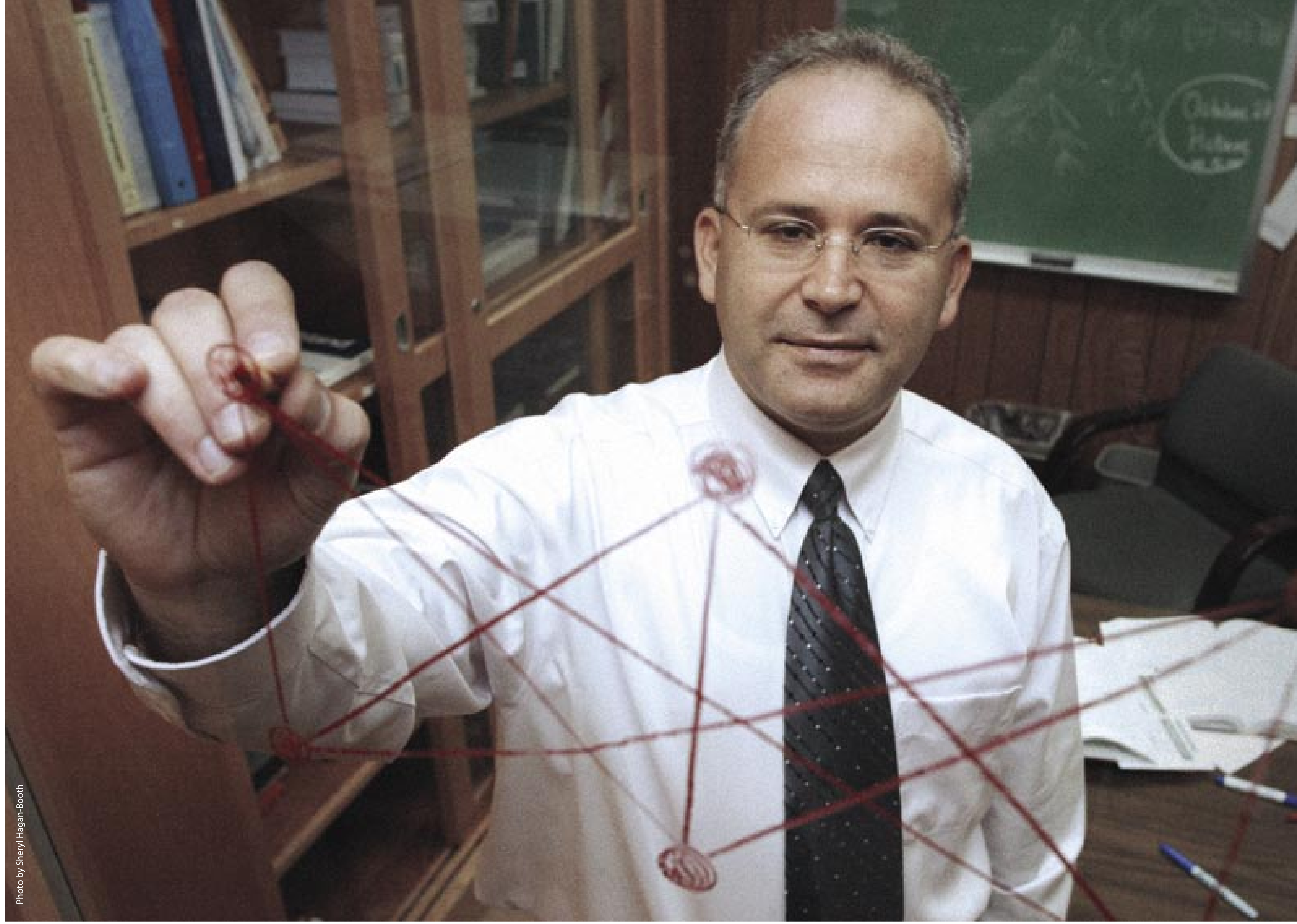
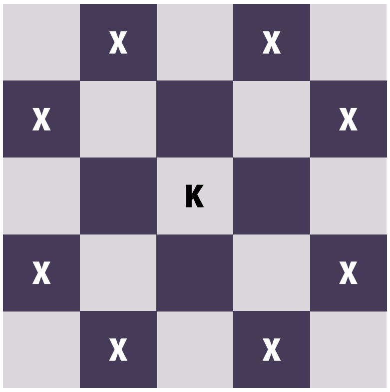


Photo by Sheryl Hagan-Booth



Here is an example that may not look like a graph problem. In chess, the knight's move consists of moving two squares horizontally or vertically and then moving one square in the perpendicular directions. For example, in the following figure a knight on the square marked K can move to any of the squares marked X. A knight's tour of an nxn board begins at some square, visits each square exactly once making legal moves, and returns to the initial square. The problem is to determine for which n a knight's tour exists.

"What I'm working on right now is the graph integrity of the computer network," Dr. Atici said.

For a community or a college campus, the graph integrity can be visualized in computer or telephone networks where efficient and reliable connections are needed with the least number of connections.

The most reliable network is an "all to all" network, but that network is not the most efficient, he said. An "all to all" phone network would require having each phone in each building connected to each phone in all other buildings. In that scenario, utility lines would fill the sky. "There'd be no place for the birds to fly," Dr. Atici said. "What you want to do is to use a minimum number of lines to provide the most reliable network," he said. "That is the main problem we are working on."

A computer network needs to be reliable to be any good. "You want to be able to communicate," he said. "If you send an email today and it is received a week later, the network is not reliable or carrying the message on time." Dr. Atici sketches a simple computer network with five computers connected to a router. If computer A wants to communicate with computer B, the connections go through a router. However, if the router is down, there's no communication. Then he draws the network as a five-sided shape with lines connecting the computers. To communicate with other computers, lines would have to connect each one. For a large network with a given number of computers, one needs to determine the minimum number of lines needed.

"This problem is hard to solve," he said. "Hard meaning there's no polynomial algorithm that can find the minimum number for every graph. You have to spend quite a bit of time on an exhaustive search that can find the best solution."

Dr. Atici and others are working on simple graphs for the answers that may solve larger problems. But even the simple graphs may not have simple answers. He sketches a network of five computers with five connections. The simplest is a pentagon shape, but he draws another sketch of the five and five connection. Determining which has the highest integrity is the puzzler. "What we try to do is play around with the smaller examples and expand that to larger examples," he said.

Then he expands his network to six computers with nine connections. He draws two examples. One has each computer with the same amount of connections; the other is unbalanced with one computer connected to four others and two with only one connection. "If I have a network of a thousand computers, what is the least number of lines to connect them?" he asked.

Two graduate students working with Dr. Atici spent three to sixth months of computing time to solve one graph theory problem. Larger problems require more time. "One has to exhaustively try each and every possibility," he said. "It's time consuming. That's why we're trying to find a theoretical bound."

Dr. Atici has published several papers on his graph theory work and hopes his research provides benefits in the future. "Someone has to do the basics and the theory," he said, noting that basic math formulas discovered thousands of years ago are used today. "I don't call myself a graph theorist," he said. "I just use the graph theory as a tool."

Graph theory has numerous applications beyond math and computer science. It can be used in research projects in areas like engineering, computer science, or any applied science, and in community planning to build highway systems or utility infrastructure.