Rakesh Vohra

Using Math to Engineer Social Systems

By Janelle Weaver

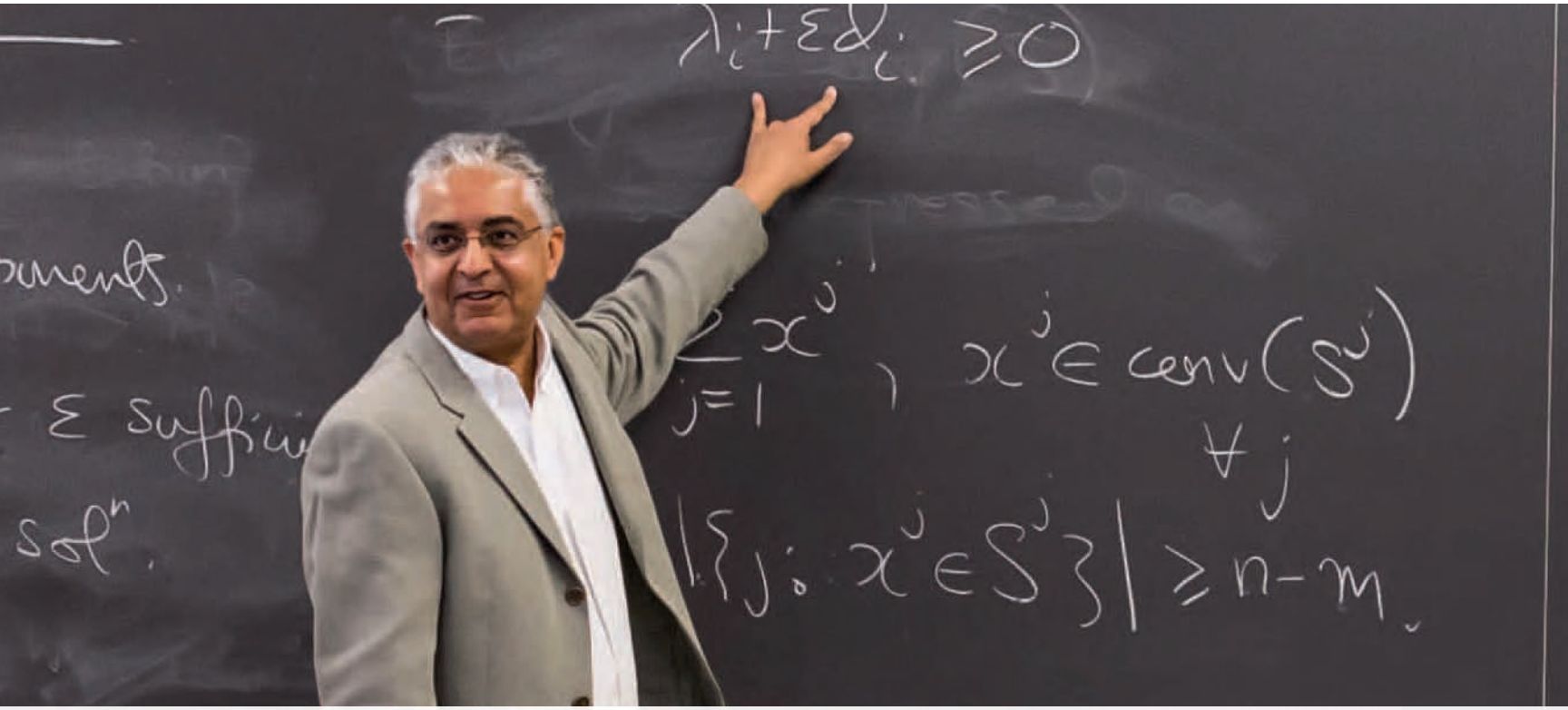
In the early hours of September 15, 2008, Lehman Brothers, then one of the nation's largest investment banks, announced that it would file for Chapter 11 bankruptcy protection. As the largest bankruptcy filing in history, this event sent shockwaves through the global markets and had devastating implications. "Interconnectedness of the financial system, some suggested, allowed Lehman's fall to threaten the stability of the entire system," says Rakesh Vohra, George A. Weiss and Lydia Bravo Weiss University Professor in the Departments of Electrical and Systems Engineering (ESE) in Penn Engineering and Economics at Wharton. "This prompted researchers like me to try to characterize the networks that would allow shocks to one part of the financial network to spread and amplify."

Recognizing the importance of understanding financial networks for shaping effective government policies, Vohra worked with Economics doctoral student Selman Erol to develop a model of network formation and systemic risk. Their findings suggested that safer economies make firms more confident, which naturally makes them take on more risk by becoming more interconnected. But the overall effect is that safer economies become too interconnected and, paradoxically, become more prone to system-wide failures. "In the long term, this work can be complemented by asking whether or how the government should intervene in the financial network architecture," Erol states. "Unintended welfare consequences at such a large scale are a big problem for policy-making, so it would be very helpful to have a better understanding of how network architecture would react to policy changes before these policy changes take effect."

Bridging Technology and Economics

Vohra is on a mission to use his strong background in mathematics to address important societal issues. Two years ago, he came to Penn from Northwestern University through the Penn Integrates Knowledge program—a University-wide interdisciplinary initiative to recruit renowned scholars. As an expert in mechanism design, an innovative area of game theory that brings together engineering, economics and computer science, Vohra has pioneered new ways to design effective markets for purposes as diverse as the power grid, the electromagnetic spectrum for wireless communications, and the matching of medical students to teaching hospitals.

"Economics has transcended business and has become not only a business tool, but also an engineering tool. Penn is now leading the discussion on connecting the technological world with economic foundations," notes



George Pappas, Joseph Moore Professor and chair of ESE. “Rakesh is one of the few people who has clearly been in the center of this emerging research area.”

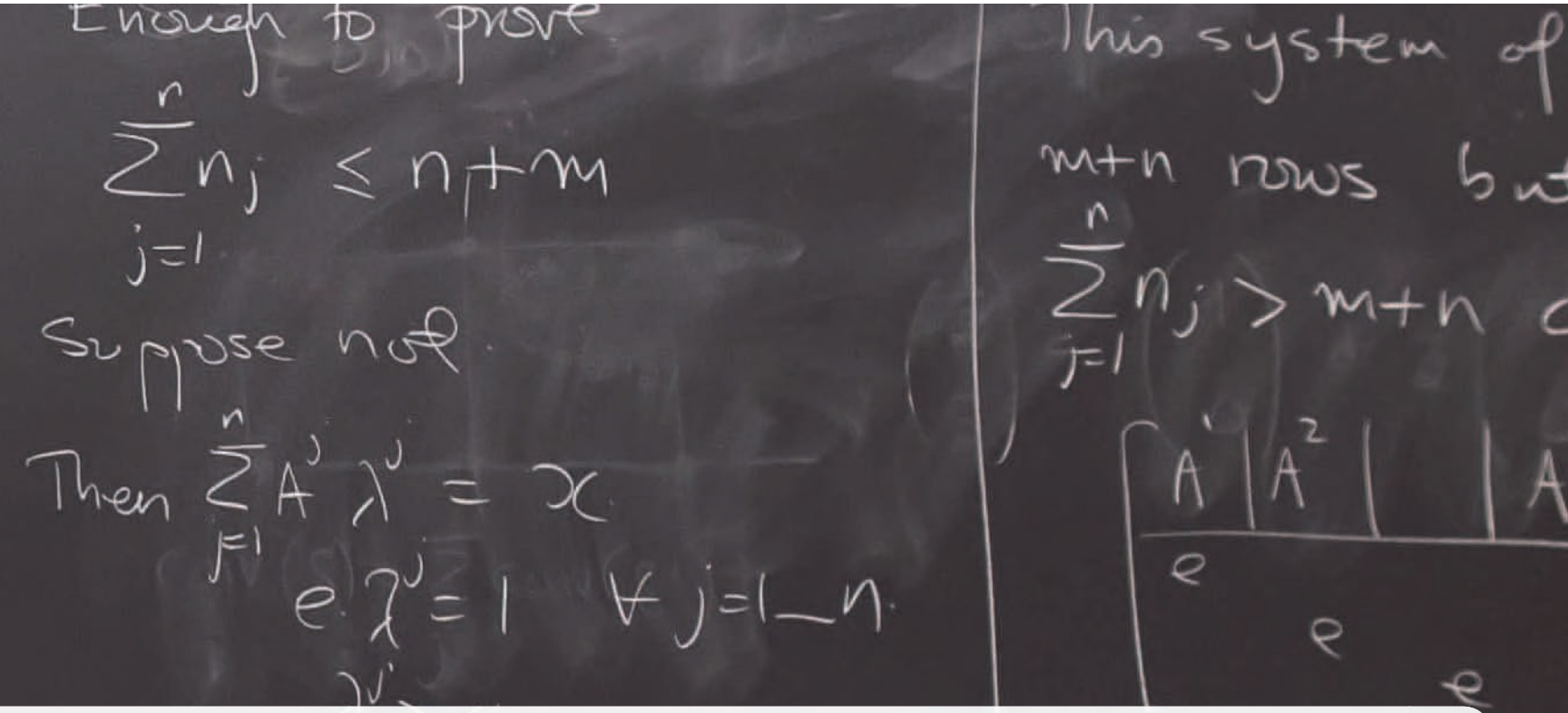
Solving Societal Problems

To study the economic roots of unfairness, Vohra is collaborating with Aaron Roth, Raj and Neera Singh Assistant Professor in Computer and Information Science (CIS), and Mallesh Pai, an assistant professor in Economics. Banks and insurance companies often use algorithms to decide the credit-worthiness of loan applicants or estimate the risk of payment default. But these algorithms could lead them to inadvertently discriminate on the basis of race, possibly due to the lack of data on underserved populations. “A simple economic argument would say that such unfairness should disappear in the face of competition,” Roth says. “If a population of credit-worthy individuals are being systematically denied loans by some financial institution, another one should jump at the opportunity to make money by serving this population and should be able to outcompete the unfair lender.”

Vohra and Roth are now working together to identify the factors that prevent this from happening. “I’m concerned that we may, by accident, end up in a world where we discriminate against various people simply because of the ways we choose to store and analyze data,” Vohra remarks. “Our findings will provide guidance to companies on how to collect and analyze data to avoid these kinds of mistakes.”

Connecting Networks to Behavior

When Vohra is not doing research, he keeps busy with leadership and teaching responsibilities. Together with Michael Kearns, National Center Professor of Management and Technology in CIS, Vohra co-directs the Warren Center for Network & Data Sciences. They have launched a vibrant speaker series and have selected and advised its first set of postdoctoral fellows. Through the Center’s initial wave of grant proposals, they are also mapping out research aims that unite diverse fields such as engineering, economics, sociology, psychology, astronomy, neuroscience, law and communications. The Warren Center, which was launched in



2013, serves as a complement to the undergraduate program in Networked & Social Systems Engineering, which began in 2011 as an unprecedented multidisciplinary program that connects the study of networks with the study of human behavior.

To teach students the connections between networks and human behavior, it's important to expose them to quantitative models for decision-making. With that goal in mind, Vohra developed a new course, ESE 204, Decision Models, which draws examples from manufacturing, finance, logistics and supply chain management. For example, a road may be built to relieve congestion in one part of a transportation network, only to unexpectedly increase congestion in another part of the network. "A decision may seem like a good idea at the local level, but globally there could be adverse impacts," Vohra states. "Humans are strategic and will respond to design changes in unintended ways. This is an important insight for engineers to understand."

Following Interesting Questions

According to Pai, one of Vohra's former doctoral students at Northwestern University, Vohra puts a lot of effort into designing novel courses and textbooks at the undergraduate, master's and doctoral levels. "In terms of teaching, what's striking, other than how good he is at it, is how seriously he takes it," Pai says. "As a past teaching assistant, I can attest to how well these thoughtfully designed courses, that aren't just following some textbook, are received by students."

Whether it's through research or teaching, Vohra is driven to probe at a deeper level the connections between the tools of engineering and economic theory, revealing elegant results that were previously thought beyond reach. "Following interesting questions is what led me to the intersection of engineering and economics," Vohra says. "I've been doing multidisciplinary research for a long time now, but I am still amazed at how useful math is for thinking about the world."