

The Network Era

After centuries of advancements in science and engineering, what might be the principal technological paradigm of the 21st century? Would you believe dots and arcs? As a doodling exercise, take a piece of paper, make about 30 dots, and then connect the dots as you see fit, with, say, 100 arcs. You can draw at random or you can create an aesthetic design, but however you do it, in the end you have a network. The dots are nodes, some kind of entities, and the arcs are edges, some kind of connector. You can think of the dots as cities and the arcs as roads that connect the cities. Or, the dots may be people, and the arcs might represent the fact that two people know each other. There are endless interpretations.

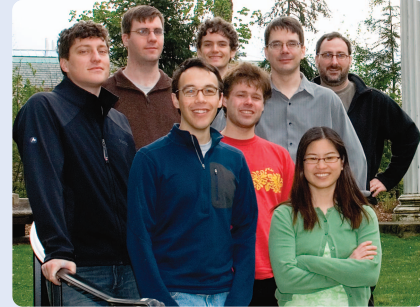
If you wish, you can make your network more intricate. You could endow some arcs with arrows, perhaps representing one-way streets. You could assign a weight to each arc representing, for example, a distance. Or, you could color each dot so that some are red and others are yellow.

Then you can ask lots of mundane but tricky questions. If any of the arcs cross each other, you might wonder whether you can untangle and redraw your network so that no arcs cross. You might wonder whether you could recolor the dots so that no red dot connects to a yellow dot. You might select a pair of dots and ask whether there is a sequence of arcs that takes you from the first dot to the second dot. You might wonder what the largest or average distance is from one dot to another dot.

Contributors



Amara, Naomi, and Lily Leonard



Back row: Joshua Bishop, David Thorsley, Samuel Burden, Eric Klavins, and John-Michael McNew. Front row: Kevin Oishi, Nils Napp, and Fayette Shaw



Bert and Niki Tanner



Calvin and Chaouki Abdallah



Francesco Bullo



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Dots and arcs, with arrows, weights, and colors. Is this the paradigm of science and technology for the 21st century? It might be. Much of science and engineering is concerned with the glorious continuum problems that have received enormous attention over the last two centuries, such



as heat flow, wave propagation, and turbulence. But advances in those areas have brought us networks of transportation systems, communication lines, and economic activity. We also became aware of ecological systems and their increasing fragility, terrorists and their secretive networks, the human genome and its combinatorial complexity, and epidemics that travel at lightning speeds. Dots and arcs.

When Chaouki Abdallah and Herbert Tanner approached me about organizing a special section on networks, I was only vaguely aware of the impact that these notions were having on science and technology. This issue of *IEEE Control Systems*

Magazine provides a glimpse of the significant impact that networks are having, not only as a mode of thinking but also as a technology that is affecting our infrastructure.

The special section in this issue has six feature articles. After the introduction by Chaouki and

Herbert, Albert-László Barabási discusses the ramifications of small worlds and scale-free networks, properties by which a network can be both robust to random failure but fragile to systematic attack. The article by Eric Klavins discusses the ability of components to spontaneously self-assemble into useful systems, not unlike molecules assembling into larger molecules. The article by Prabar Barooah and João Hespanha presents strategies for collecting and processing data from a network to estimate global quantities, such as time or location. Next, inspired by flocking in groups of animals, Sonia Martínez, Jorge Cortés, and Francesco Bullo dis-

cuss how local interaction among nodes leads to global properties. Along the same lines, Derek Paley, Naomi Leonard, Rodolphe Sepulchre, Daniel Grünbaum, and Julia Parrish present control strategies that give rise to coordinated motion.

In addition to the special section, this issue of *IEEE Control Systems Magazine* includes numerous articles of special interest. For "Applications of Control," Sandipan Mishra, Joshua Coaplen, and Masayoshi Tomizuka explain how to implement iterative learning control for wafer processing when the disturbances aren't quite periodic. In "Focus on Education," Emmanuel Collins, Jr. and Abdollah Homaifar describe the development and status of control engineering programs at historically black colleges and universities in the United States. We also have a report on the 45th Conference on Decision and Control held in December 2006, as well as a product review on the Polynomial Toolbox.

As usual, we appreciate your feedback. We're the dots, and the arcs are available. I hope to hear from you.

Dennis S. Bernstein



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