DYNAMICAL SYSTEMS: **CHANGE IS THE CONSTANT**

More than thirty UCSB faculty are connected with the inherently interdisciplinary Center for Control, Dynamical Systems, and Computation (CCDC), with strong representation from electrical engineering and mechanical engineering, and additional affiliates from mathematics, computer science, and chemical engineering. It is an area where, says center director, **Andrew Teel,** junior faculty are making significant contributions in a variety of areas. Here, we summarize projects from several of those rising stars.

THE AUTONOMOUS FLEET

In the future, fleets of autonomous ride-sharing vehicles — think Lyft and Uber without drivers — will become reality. So how will they work?

Mahnoosh Alizadeh and **Ramtin Pedarsani,** assistant professors in the Department of Electrical and Computer Engineering, are working on it. They are applying mathematical analysis to develop algorithms for controlling dynamical systems, which are rife with constantly changing variables. In this case, they are developing an optimized system for a fleet of driverless ride-sharing vehicles.

"Autonomous vehicles [AVs] are going to be the future," says Pedarsani. As such, adds Alizadeh, "We're working at the macroscale on how to control them and price rides to maximize either social welfare or the platform operator's profit."

An AV ride-sharing system presents an opportunity to optimize efficiency, because, while human drivers have their own agendas, Pedarsani notes, "AVs can be altruistic."

But modeling and implementing such a system is an enormously complex challenge. For instance, Alizadeh says, "After dropping off a rider, should a car wait in place for another ride request or for demand to increase at that location? Should it go pick up another customer or go to a location that has higher demand? If it's an electric vehicle, should it go to a solar charging station?"

"That's the dynamical system," Pedarsani says. "Demand and traffic change constantly throughout the day, and human drivers sharing the road are also involved. The dynamics are highly volatile. But you can address all that and simultaneously adjust the price according to demand," while ensuring, Alizadeh notes, that "enough cars are available so that the price for riders is reasonable, but not so low that too many rides are requested and long waits ensue."

To design a control algorithm for such a complicated problem, the first step is to develop a mathematical model that represents the key features of the system. "We try to abstract out the important parts," Alizadeh says. "We can't capture everything, but we capture what matters in terms of such important properties as system stability and efficiency."

To develop a computationally efficient and near-optimal solution, the researchers are applying a new tool from machine learning called *deep reinforcement learning*.

"Reinforcement learning can solve large-scale dynamical control problems without the need to know every detail of the dynamics," Pedarsani says. "This has not been done yet, but we have some promising preliminary findings."

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GENETIC CIRCUITS

In one of his main projects, mechanical engineering assistant professor **Enoch Yeung** is investigating control mechanisms located inside natural biological organisms that are the critical points for influencing synthetic gene circuitry. The work involves introducing genetic circuits, often designed to have some kind of logic-gate function or switching behavior, into bacteria and observing how the circuits impact the host and how the host organism influences the circuits.

"We are trying to model the interface between a host's intrinsic dynamics and the dynamics in synthetic genetic circuits," Yeung says. "We're building genetic circuits, from the bottom-up, that the cell has not seen before. We then model the progressive response and track emergent behaviors while evaluating the ability of the cells to enact a computational program, such as a logic gate or toggle switch."

Yeung says that the long-term goal of the research is to develop data-driven design algorithms for engineering genetic circuits with a minimal footprint on the organism. "We look at high-throughput experimental data from transcriptomics [the complete set of RNA transcripts produced by the genome], proteomics [proteins and their functions], and single-cell behavior, and from that, we identify genetic-circuit components that we should tune or refactor in order to minimize the impact."

HUMANS AND ENGINEERED SYSTEMS

A great deal of ECE professor **Jason Marden**'s research emanates from the simple observation that "humans are complicated."

"If you're thinking about an engineered system that will be utilized by people, it's fundamentally important to understand how people make decisions," says Marden, whose research integrates engineering, control theory, and economics theory.

In one example of how humans impact systems, he describes two versions of a traffic-flow system leading from point A to point B — the baseline system and a duplicate of it that differs only in having one additional route.

"So, you take the new route because it helps you out," he says. "But it also helps out other people, and they gravitate to it. Suddenly, we're all using the new way, and the traffic on it is worse than on the old way. People trying to minimize their own congestion does not equate to the system operating desirably."

One way to address such system breakdown is through incentives, perhaps in the form of a tax or a subsidy, but different groups of people differ widely in their responses to various incentives.

The question for Marden becomes how to design incentives that will effectively influence users — i.e. encouraging them to use the various routes in ways that minimize congestion — and also be very robust to such variation but not make the situation worse.

Achieving that, he says, "is fundamentally hard."

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