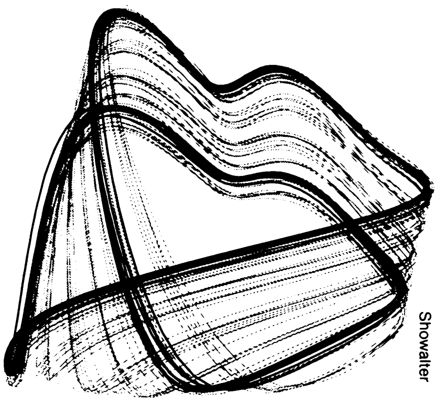
Physical Science

Controlling chemical chaos

Pale yellow, then colorless. Pale yellow, then colorless. First one color, then none.

Instead of mixing to produce a uniformly colored solution, certain combinations of reacting chemicals display regularly repeating patterns of alternating colors. By carefully adjusting the concentrations of the ingredients required for these chemical oscillators, researchers can also transform this periodic behavior into the erratic, unpredictable changes characteristic of a chaotic system. Now Kenneth Showalter and his co-workers at West Virginia University in Morgantown have demonstrated that they can keep such a chemically unstable system oscillating regularly by applying a sequence of small adjustments to the concentrations of some of the chemicals involved in the reaction.


Showalter

Plot characterizing voltage fluctuations in a chaotic chemical system

"This is the first example of controlling chaos in a chemical system," Showalter says. Researchers had previously used similar techniques for controlling the chaotic behavior of heart tissue (SN: 9/5/92, p.156), solid-state lasers (SN: 2/22/92, p.119), and magnetoelastic ribbons (SN: 1/26/91, p.60). Showalter and his group report their findings in the Jan. 21 NATURE.

The researchers carried out their experiment in a tank continuously fed separate solutions of malonic acid, cerium sulfate, and sodium bromate. One pump delivered malonic acid at a fixed flow rate, and another pump delivered the cerium and bromate solutions at a rate regulated by a computer. The reaction was monitored by tracking fluctuations in the voltage of an electrode sensitive to bromide ions (a reaction product).

Showalter and his co-workers used these voltage measurements to plot a three-dimensional portrait of the system's dynamical behavior (see diagram). One coordinate represents the voltage at a given moment, the second coordinate represents the voltage 38 seconds earlier, and the third represents the voltage another 38 seconds earlier. If the voltage were to remain constant throughout the experiment, the plot would consist of a single point. However, because the voltage fluctuates erratically, the plotted points trace out a complicated shape (dotted lines). Using data obtained from such a plot, the researchers can compute how much and when to increase or decrease the cerium and bromate flow rate to stabilize the voltage into a repeating pattern (solid line).

Using this technique, Showalter and his group could not only stabilize oscillatory behavior with a given period but also switch that behavior readily from one period to another—all by making modest adjustments to the flow rates. "I think the real challenge in this business will be controlling chaos in spatial-temporal systems," which display moving waves of color — often in the shape of spirals or concentric rings—in thin liquid films, Showalter says. "There's also a tremendous opportunity there for biological applications."

Record magnetic field

Last month, a specially designed "hybrid" magnet at the Massachusetts Institute of Technology's Francis Bitter National Magnet Laboratory achieved a record magnetic field of 37.2 teslas, about 700,000 times greater than Earth's magnetic field.

Technology

New ocean views may cut shipping costs

In the transoceanic shipping business, the cheapest and speediest path between two points is not always a straight line. By using new and improved satellite data on ocean currents to chart courses, the shipping industry may soon reap substantial savings in fuel costs, says civil engineer Mark R. McCord of Ohio State University in Columbus.

Transportation researchers had developed methods of calculating the cheapest, swiftest, and safest shipping routes by taking into account the effects of weather, waves, and other environmental factors. But seldom did they base calculations specifically on the effects of ocean currents, largely because of insufficiently detailed and up-to-date measurements of such currents, McCord explains in a draft paper presented in mid-January in Washington, D.C., at a meeting of the National Research Council's Transportation Research Board.

McCord and former Ohio State graduate student Hong K. Lo found that continually calculating both course and speed changes required an unacceptable amount of computer time. However, route planners can still gain significant fuel savings by computing heading changes alone, which requires far less number crunching. Thus, a captain could set the ship's throttle at a constant speed and simply change course at points calculated by the computer, maximizing the benefits of favorable currents and minimizing the effects of unfavorable ones.

McCord says he embarked on the study partly in anticipation of higher quality oceanographic data from the TOPEX/Poseidon satellite, built jointly by the U.S. and French space agencies and launched into orbit on Aug. 10, 1992 (SN: 11/21/92, p.340). With the new data, shipping companies may achieve fuel savings of 1 to 7 percent, depending on the strength and direction of the currents encountered. Considering NASA's enthusiasm for such practical spin-offs from its scientific programs, "it may be worth it to the U.S. shipping industry to pay a little money for an extra person or two to get the data out in real time so [route planners] can use it," says McCord.

Remedies for tollbooth trauma

Next to radar traps and malevolent tractor-trailer drivers, nothing strikes more frustration in the hearts of motorists than crowded toll plazas. Fortunately, both technology and hope spring eternal: A new study shows that relatively minor changes in toll-plaza design can dramatically decrease congestion.

In a presentation at the Transportation Research Board meeting, Mitsuru Saito of the Institute for Transportation Systems at the City College of New York discussed two increasingly popular methods of alleviating toll-plaza congestion.

In electronic toll collection (ETC), motorists keep a magnetic debit card on their dashboards. Sensing equipment in the tollbooth extracts a tithe automatically from a prearranged account as the car passes. "You don't have to stop — that's the key point," says Saito.

Toll-plaza managers can also build "branch tollbooths," a set of additional booths beyond the main toll barrier and fed by lanes passing through it. These increase the capacity of the plaza without widening the facility — an option often unavailable in heavily developed urban settings.

Based on previous surveys of congested toll plazas and direct observations of several plazas on New Jersey's Garden State Parkway, Saito developed a computer simulation to test various configurations of ETC and branch tollbooths. The results suggest that at plazas in and around New York City, where per-car delays sometimes mount to 25 minutes, ETC and branch toll lanes work best together. "Branch tollbooths can reduce congestion to a certain level," Saito says. "If you want to reduce delay to 10 to 15 seconds per vehicle, then you need ETC as well as branch tollbooths."