Contingencies

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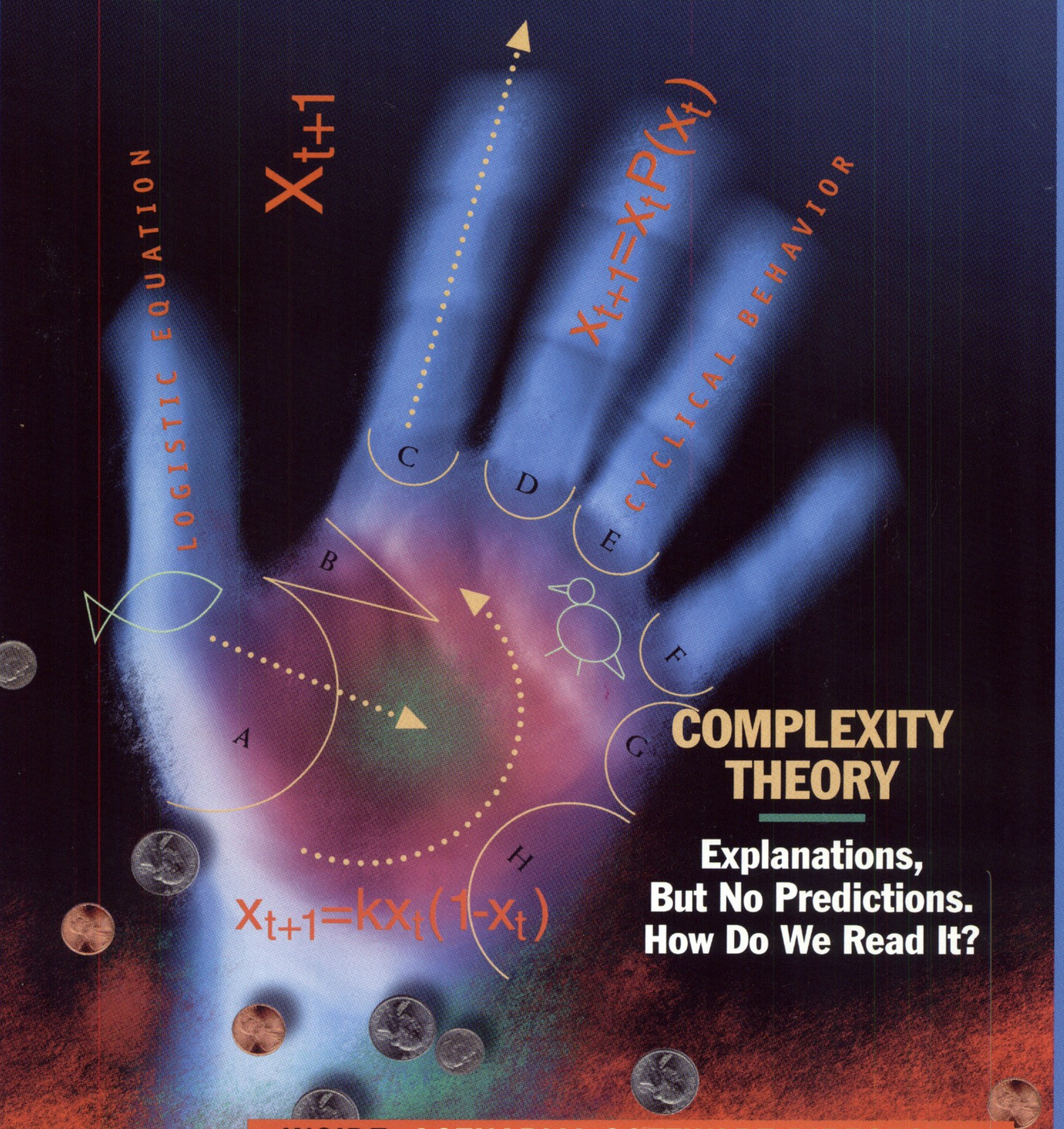

COMPLEXITY THEORY

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Modeling Danger

Computer Simulations Analyze Pollution Effects, Forecast Problems

BY PAOLO ZANNETTI

Nearly every week, we hear about accidental releases of hazardous materials into the atmosphere in the wake of a fire, or mechanical failure of a pipeline, valve, or container. Most of these releases end up as little more than a nuisance, but some force nearby residents to evacuate their homes and businesses.

Most people are aware as well of soil contamination from industrial and agricultural practices, and the danger that migrating pollutants can pose to surface water and groundwater systems.

To analyze the effects—both actual and potential—of hazardous releases, computer simulation techniques play an increasingly important role. The use of computer models was limited and only partially justified until about 5 years ago; models still required large mainframe computers and were expensive to run. Now, the new generation of inexpensive computer software and hardware has reduced costs dramatically.

A number of firms are offering environmental consulting services in the marketplace today, and most are capable of using computer modeling to perform technical analysis. Their clients can expect to pay between $20,000 and $50,000 for their services. Environmental consultants that also offer litigation support can be harder to find, and may charge as much as $100,000 by the end of a complex legal proceeding. Satisfied clients, however, would think that the benefits of such specialized service outweigh the costs, especially when the possibility of multimillion-dollar damage awards looms in the background.

Specialized programs can provide an objective tool for two types of analysis: *what happened*, in which we reconstruct and understand an environmental accident after it occurs—for example, in order to assess individual responsibilities; and *what if*, in which we explore a hypothetical pollution scenario to assess expected consequences and liabilities.

Computer simulation models—when used correctly and with reliable parameters, data, and assumptions—are capable of performing several important tasks. They simulate the transport and fate of pollutants in the environment, calculate population and ecological exposure, quantify adverse effects and damages, and provide a visual image of the extent and characteristics of pollution.

Computerized visualization allows us to verify the accuracy of the simulations and make them understandable to the non-mathematician. Few people want to master the mathematical intricacies that go into making environmental models. But almost everyone can understand color pictures, or an animation that shows a pollutant being injected into the environment at point A and the concentration migrating to point B. Good visualization is always useful, and it is sometimes essential—for example, when the results will need to be used in litigation, especially in a jury trial.

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Computer Modeling Comes of Age

During the past 25 years, the field of environmental modeling has evolved from a purely scientific endeavor into a practical methodology for environmental protection, regulatory compliance, urban and industrial planning, and litigation support. In fact, there are few (and often no) alternatives. For example, in "what happened" analyses of environmental accidents involving the accidental release of pollutants into the air, only computer models can provide estimates of the pollutant concentration to which people were exposed. These are the only "objective" estimates available. (In fact, all other estimates are, necessarily, subjective.)

Computer-generated pollution concentrations are generally determined by simulating local meteorology at the time of the accident and, from that, the transport and fate of the pollutants carried and dispersed by atmospheric turbulence. Figure 1 illustrates a hypothetical air pollution accident in the San Francisco Bay area with a plume originating from a Menlo Park, California, office building.

With soil and groundwater cleanups, too, only computer models provide an objective assessment of fractional responsibility. They offer the most accurate and efficient means of calculating how much responsibility a company bears for soil pollution when the pollution has been generated in the same location by different groups, activities, and corporations over many years.

Particularly in "what if" scenarios, the unique benefits of computer simulation are undeniable. Past accidents can be evaluated through field investigation, laboratory analysis, and subjective interpretations based on practical engineering experience. When it comes to hypothetical accidents, though, the computer is the only tool we have.

An *environmental model* is a computer program that provides outputs (assessments and forecasts) based on the input parameters and assumptions provided by the user. As always, the rule "garbage in, garbage out" applies. For example, if you enter the wrong wind direction in an atmospheric simulation, you can't blame the computer model for showing the pollutants moving away from the actual area of impact.

Computer models can simulate the transport and fate of pollution in all environmental media: air, surface water, soil, groundwater, and living organisms. They can simulate:

- *transport* by including terms such as atmospheric wind
- *diffusion* by allowing pollution to diminish over time
- the *chemistry* of environmental accidents by incorporating chemical reaction terms; some models include hundreds, and even thousands, of chemical reactions
- *deposition* by allowing, for example, a fraction of atmospheric pollution to deposit at ground level, or a fraction of water pollution to deposit sediments at the bottom of a body of water.

Computer models can also calculate the expected consequences of pollution, such as adverse effects on human health, and damages expressed by monetary values, such as remediation costs.

In addition to making assessments and forecasts, environmental models can be used to calculate a range of uncertainty about the answers, as illustrated in Figure 2. In other words, a model can provide an estimate expressed by a probabilistic range: for example, the pollution level, with a 95% probability of occurrence between 49 parts per million (ppm) and 58 ppm, or damages, with an associated probability of 80% between \$20 million and \$40 million. Probabilistic results are more scientifically sound than single-point estimates, although it may be harder for the general public—and even decision makers—to understand and evaluate calculations and opinions based on, or expressed as, probabilities.

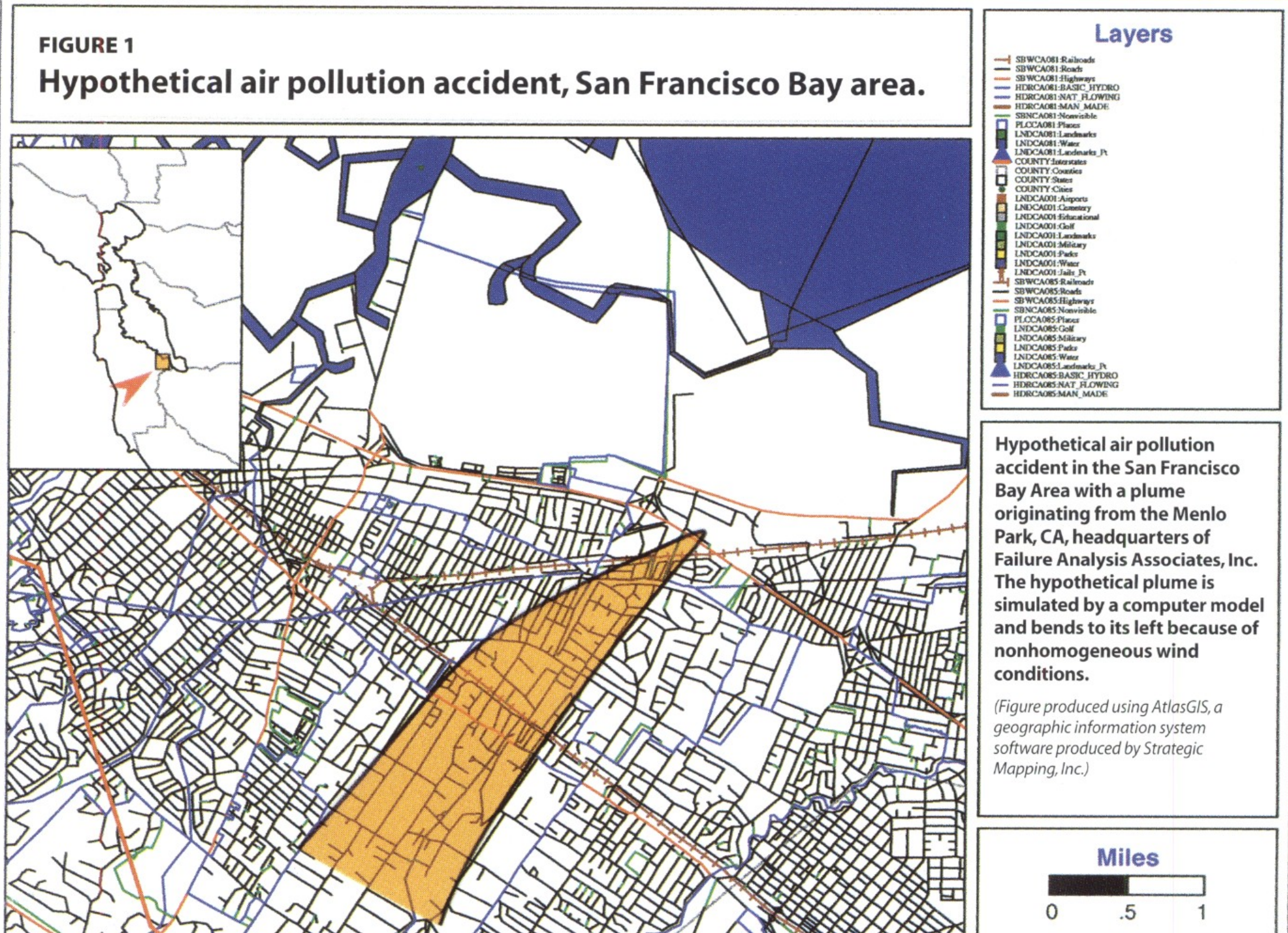
Modeling in the Courtroom

We used computer modeling in recent litigation for the benefit of our client, the defendant. The plaintiff had sued the company for alleged health damage caused by the accidental release of a chemical into the atmosphere. The release had admittedly affected several people in the region, but the plaintiff appeared to be located outside the geographic area of contamination. Our role was to reconstruct the trajectory of the plume and assess the chemical concentration, if any, to which the plaintiff was exposed.

One of the first, and most important, decisions in this case was to select an appropriate plume dispersion model to simulate the accidental release and its trajectory in the region. Our choices included a standard model recommended by the U.S. Environmen-

FIGURE 1

Hypothetical air pollution accident, San Francisco Bay area.



Hypothetical air pollution accident in the San Francisco Bay Area with a plume originating from the Menlo Park, CA, headquarters of Failure Analysis Associates, Inc. The hypothetical plume is simulated by a computer model and bends to its left because of nonhomogeneous wind conditions.

(Figure produced using AtlasGIS, a geographic information system software produced by Strategic Mapping, Inc.)

tal Protection Agency (EPA) and several other, more sophisticated models. EPA-preferred models treat a plume as if it travels in a straight line. In this case, however, we knew that the plume didn't move that way.

We had already displayed all the locations of all the complaints about chemical odors arising from the accident on a computerized map of the region. It was clear, from the map, that the plume bent about 30 degrees on the left along its path downwind. Had we used an EPA model in this case, there would have been a noticeable discrepancy between model outputs and the actual pattern of odor complaints. Our plume reconstruction with this model, therefore, would not have been credible.

We chose a more sophisticated plume model that was capable of changing the plume direction along its path, according to local meteorology. We also collected all available meteorological data in the region during the hours of the accident and used this information to drive the plume model.

The results were successful, in the sense that the plume model correctly simulated a bending plume affecting different areas at different times, in full agreement with the pattern of odor complaints recorded in the area. With a plume reconstruction that was faithful and incontestable, we could show that the plaintiff was located outside the plume's path. We were able to formulate a convincing opinion on this matter, and the case ended successfully for our client.

Well-prepared computer visualization helped make the case clear and understandable to the jury. We used a computerized geographical information system to display the region, the plume's trajectory and evolution over time, the locations of the odor complaints, and the location of the plaintiff. We used color transparencies to present the results in court. But if we had a chance to work on a case like this again, we would connect a portable computer to a liquid crystal display projector and display all the images directly from the computer.

Computer modeling is an indispensable tool for performing environmental risk assessments. In particular, models can help corporations and their insurers objectively evaluate past accidents and contamination cases and correctly allocate proportionate responsibilities. This is the only methodology that can forecast hypothetical pollution scenarios and, therefore, quantify potential liabilities.

I admit to my own bias as a provider of computer modeling service. Still, I think carriers that don't make full use of the newest generation of environmental models—no matter with whom they contract—in their environmental claims adjustment process are likely to overpay their claims.

The underwriting process would similarly benefit from environmental models, which would add an important element of quantitative precision to the differentiation and classification of environmental risks. □

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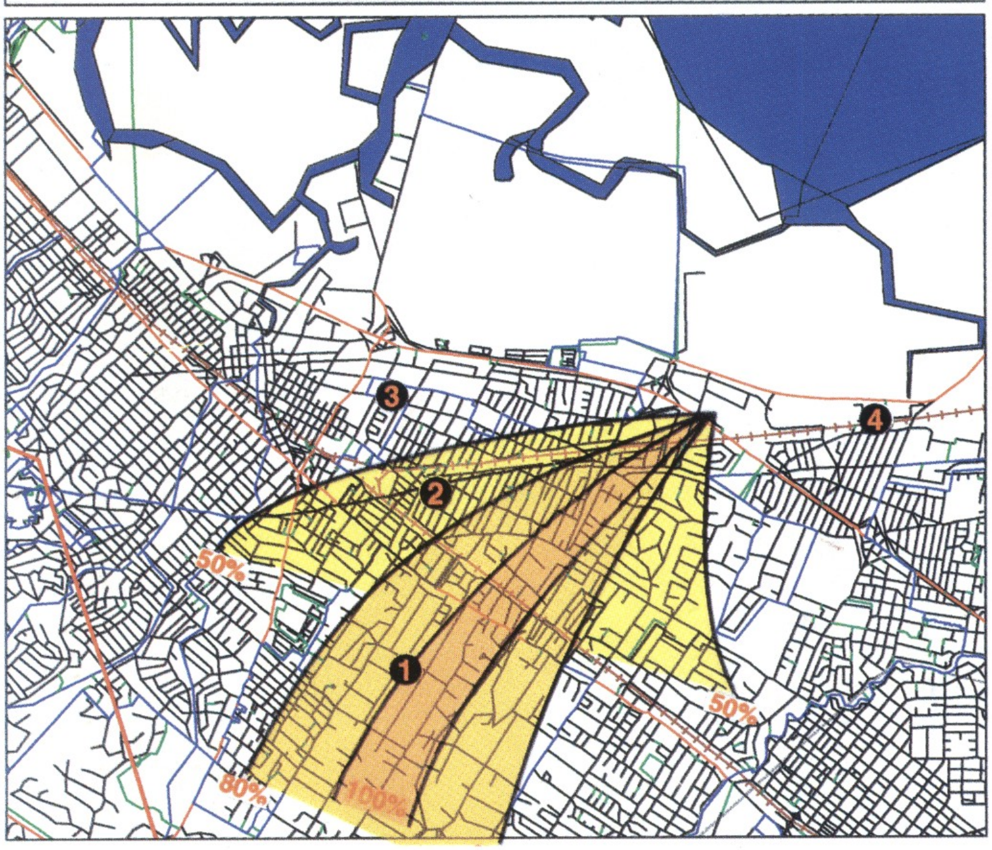
FIGURE 2
Probabilistic estimate provided by the model.



Inclusion of uncertainty analysis in the hypothetical accident simulated in Figure 1. Different probabilities are associated with different types of plume behavior. This example would lead to the following conclusions: a person located in point 1 was very probably affected by the plume; a person located in point 2 was probably affected; a person located in point 3 was probably not affected; a person located in point 4 was very probably not affected