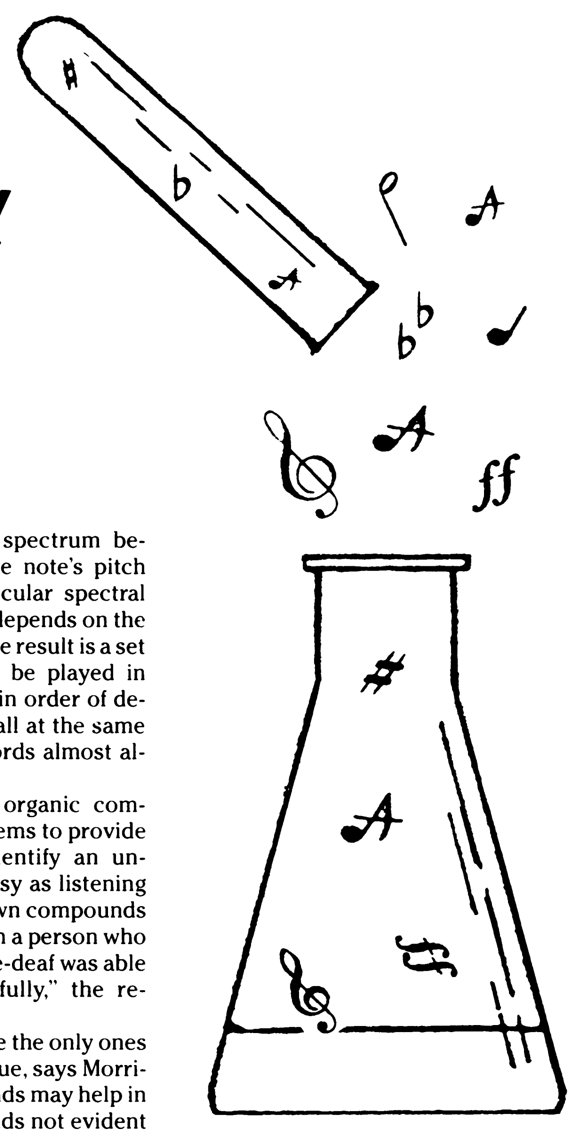
Some labs are alive with...

The Sound of Data



By IVARS PETERSON

Ethanol sounds like an extraterrestrial dance tune. Polystyrene modulates from a dark, demented fugue into an icy tinkle. Acetic acid echoes with a quirky syncopation.

These are some of the sounds that fill a lab when a chemical compound's "fingerprint" — the characteristic peaks and valleys of its infrared spectrum — is interpreted as a sequence of musical notes. Developed by chemists Robert C. Morrison, David C. Sowell and David Lunney, this scheme is part of a project at East Carolina University (ECU) in Greenville, N.C., to help blind chemistry students work in a laboratory.

Other labs feature different sounds. Over the last few years, a handful of researchers have also started to explore ways of using sound to sort out statistical relationships. Out of their work has come the moan of economic depressions, the rumble of seismic data pointing toward oil reservoirs and the clang of victory in the shifting sounds of a simulated battle during a war game.

The use of sound is a promising way of making sense of masses of data because the human ear is so good at routine tasks like recognizing a voice, picking out a single word in a cacophony of cocktail chatter or hearing a flute's sweet tone in the midst of an orchestral romp. The ear can integrate disparate sounds into a harmonious whole or detect subtle nuances buried in noise.

"The human sense of hearing has remarkable powers of pattern recognition," says Morrison, "but hearing has been largely ignored as a means of searching for patterns in numerical data."

Chemists glean a great deal of information from just a glance at a chemical compound's infrared spectrum, says Morrison. The challenge is to find a way of presenting this information in the form of sounds so that listening is enough, for example, to identify an unknown compound.

In the ECU scheme, each major feature in a substance's infrared spectrum becomes a musical note. The note's pitch depends on where a particular spectral peak falls, and its duration depends on the peak's height (intensity). The result is a set of musical notes that can be played in order of descending pitch, in order of decreasing peak intensity or all at the same time as a chord. These chords almost always jar the ear.

Remarkably, for simple organic compounds, the chord alone seems to provide enough information to identify an unknown substance. It's as easy as listening to a set of chords from known compounds until a match is found. "Even a person who professes himself to be tone-deaf was able to match chords successfully," the researchers report.

Blind students may not be the only ones to benefit from this technique, says Morrison. Data presented as sounds may help in picking out patterns or trends not evident when displayed in graph or chart form.

In 1980, Joseph J. Mezrich of the Exxon Research and Engineering Co. in Annandale, N.J., began looking for better ways to present data. "We have really great computers between our ears," says Mezrich. "It seemed to me a very exciting opportunity to try to tackle statistics problems by taking advantage of the perceptual skills people have."

Mezrich, working with Rush Slivjanovski and Steven P. Frysinger, who is now at AT&T Bell Laboratories in Murray Hill, N.J., came up with a unique blend of computer animation and computer music for presenting complex data. "We found sound to be a very powerful tool," says Frysinger.

This method seems to work best with data involving several variables that each change in value over time. For example, an economist looking for indications of an impending depression may track car sales as one variable, unemployment figures as another, housing starts as a third, the value of the dollar overseas as a fourth and so on. As the values of these variables rise and fall from month to month, certain combinations or patterns in the data could foreshadow serious economic problems.

Nevertheless, the overwhelming amount of data makes picking out a useful pattern or trend very difficult. One way of handling the problem is to compress the variables into a single index, but, says Frysinger, "You're throwing out information." Computers, unless they're told exactly what to look for, also have trouble finding patterns. On the other hand, human beings are very good at noticing trends, he says, "if we're given the information in the right form."

That form could very well involve sound. Looking for patterns when variables are expressed as the pitch, loudness, duration and other properties of musical notes isn't particularly farfetched. "If you think of an orchestral piece," says Mezrich, "that's what it is: some variables that are changing with time."

Says Frysinger, "You take the indicators and play them like a movie with a soundtrack. Each of the indicators has its own melody, analogous to a fugue."

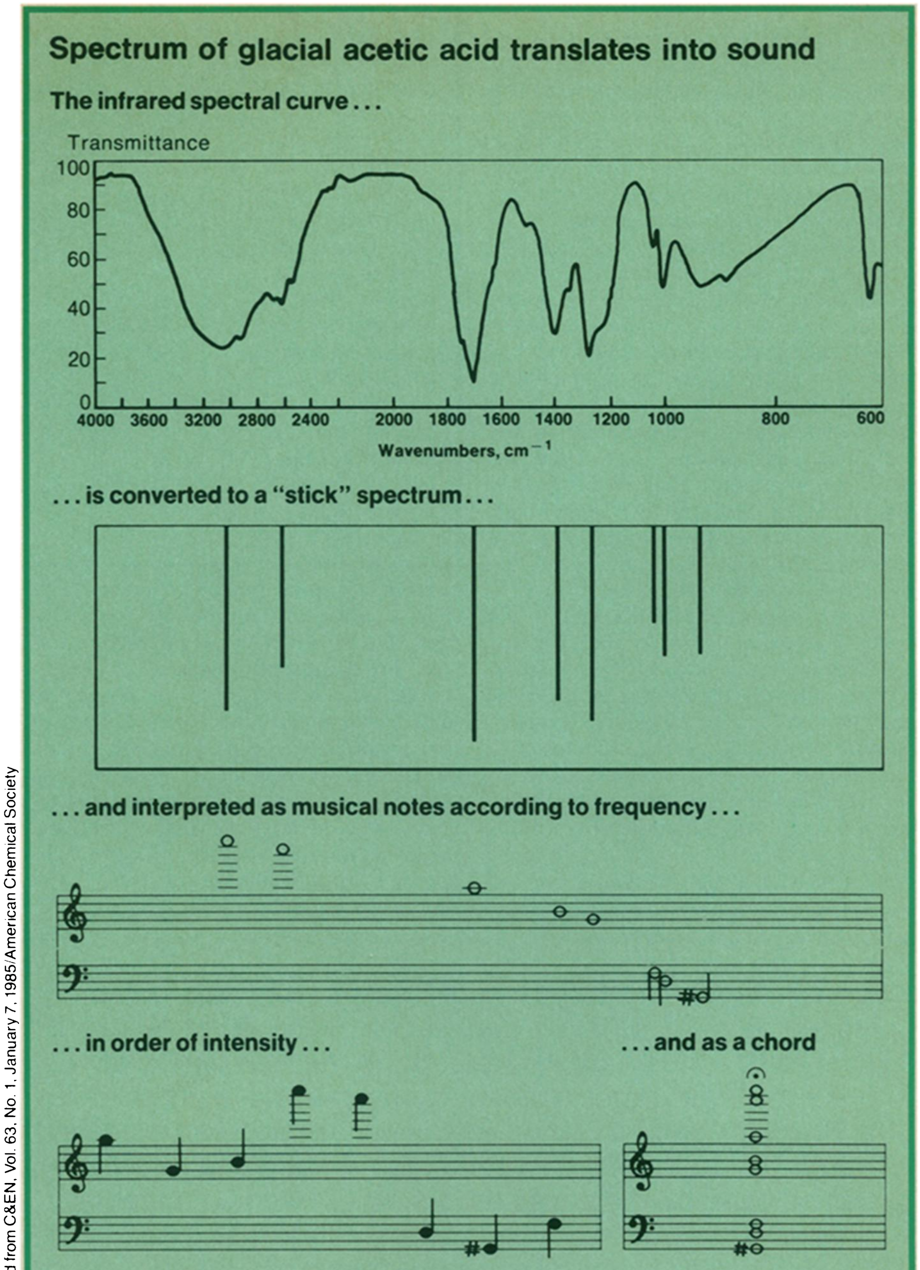
"As I see it," says Mezrich, "it's primarily a tool for exploratory data analysis. Ultimately, you want to assign numbers to your insight, but this is a mechanism for getting the insights in the first place."

Mezrich and Frysinger experimented with economic data, partly because so much was readily available. For Exxon, this technique now looks promising for analyzing seismic data collected in the search for oil. Mezrich is also exploring the possibility of using some form of sound to represent the complicated sequences of nucleotides in DNA molecules so that molecular biologists can pick out patterns more easily.

"The human pattern-perceiving capability is there; the technology certainly is there," says Mezrich. Today's computers, with color graphics and sound synthesizers, let you do almost anything. "The tough problem is thinking of a good representation," he says.

Mezrich and Frysinger found, for example, that converting numbers directly into frequencies and then into sound didn't work very well. "It just wasn't hummable," says Frysinger. Instead, translating data into musical notes — the strictly limited frequencies of a chromatic, diatonic scale —was much more effective.

"You have to deal with the fact that we grow up in a world with certain kinds of melodic content," says Mezrich. "When you want to recognize something, you have to deal with the language you already have in your head."



Source for spectrum of glacial acetic acid: Aldrich Library of FT-IR Spectra, First Edition, by Charles J. Pouchert

Pitch and duration aren't the only characteristics of a sound useful for representing a range of statistical data. Sara A. Bly, now with Xerox Corp. in Palo Alto, Calif., included in her studies characteristics like "waveshape" (varying from the pure tone of a sinusoidal wave to the ragged buzz of random fluctuations) and loudness.

"I wanted to look at some of the problems that people were already having trouble studying visually," says Bly. In her 1982 doctoral thesis done at the Lawrence Livermore (Calif.) National Laboratory, she showed, for example, that sound encoding of data was useful for deciding into which of a small number of categories a particular sample falls.

She tested her method on the problem of classifying a flower as one of three species. There were four variables (sepal length and width, and petal length and width). These characteristics were converted into variations in pitch, volume, duration and waveshape, giving each flower sample its own distinctive musical note. Almost everyone who tried the test successfully placed each sample in the correct slot. A similar experiment using gamma ray spectra from samples that each fell into one of four categories (types of materials) worked just as well.

Bly also worked with a group of researchers interested in battlefield simulations. These particular simulations are run on a computer from start to finish without human intervention and provide information about the state of the battle, step by step during its duration. "To an analyst interested in the results of the simulated battle," says Bly, "this information is often an overwhelming collection of statistics. Nevertheless, it is important to note the battle characteristics which yield various results."

Bly came up with "battle songs" to help the analysts. For simplicity, she used only four variables to characterize a two-sided battle. One side was encoded as a pure tone, while the opposition had a noisy buzz. Pitch represented the number of military units at the front, and loudness the number of units moving up to the front or retreating. Thus, a high, loud note signified a very strong battlefield position.

"It was possible to listen to both notes simultaneously," says Bly, "and therefore, to follow the progress of each side in the battle." However, she notes, "Battles with similar outcomes [did] not necessarily produce similar songs."

Says Frysinger, "There are many dimensions and many mappings [from data to sound] possible. To understand them we have to understand psychoacoustics."

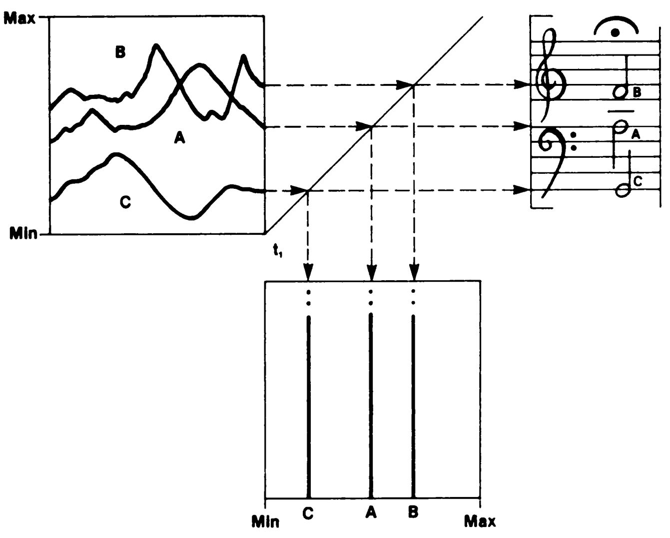
The key, he says, is to pick the right combination of display and sound to detect a correlation or to find a meaningful signal in the midst of noise. Very little is known about how effective different means of presenting data are for seeing trends or classifying complex patterns.

"All of this needs more work," says Bly. In the case of sound, one problem is that people seem to need some sort of standard reference. "Sounds themselves are more transient than a visual display," she says. Thus, analysts must be able to refer to the standards easily.

In addition, sound characteristics are not totally independent. Even when the amplitude of a sound stays constant, for example, the human ear perceives changes in loudness when the frequency varies. Cultural differences may also alter the technique's effectiveness.

Many different mathematical techniques are available for analyzing data, and the results can be plotted graphically in many different ways. But these are generally limited to two dimensions. Visualizing data involving several variables that change over time is particularly difficult. "Sound gives you additional dimensions," says Bly. "It gives you a different impression of your data."

Bly sees sound as an integral part of computer systems that allow a researcher to try a variety of different ways to present data. "I'm a big believer in interactive systems for doing data analysis," she says. "Essentially, you're going on a treasure hunt, trying to find clues." With such a system, researchers could examine their data using many different techniques—making plots, calculating statistical parameters, changing sounds — switching from one representation to another until they find one that works best for them.



The values of variables (say, economic data) at a particular time can be represented as a set of musical notes played at the same time or as colored lines on a video screen. As each variable changes in value, the pitch of the notes rises and falls and the lines shift back and forth across the screen.

Mezrich et al./J. of the Am. Statistical Assn.

"There are simply too few people working on this yet," says Bly. "I think there's a lot of potential there that we're just barely beginning to tap."

Adds Mezrich, "The hardware to do this is really quite inexpensive." More and more computers can handle sophisticated computer graphics and synthesize a wide range of sounds. "What's very exciting," he says, "is that people with computers at home can do this. There's an opportunity for a lot of fun." □