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The Grammy in Mathematics

Mathematician nominated for award for restoring the only known recording of a live Woody Guthrie performance

Julie J. Rehmeyer

Shortly after September 11, 2001, a small, heavy package wrapped in brown paper arrived in the mail at the Woody Guthrie Archives in New York City. Inside was a mess of wires.

Guthrie's daughter Nora eventually figured out that the suspicious package wasn't a bomb, but rather a recording of her father on a device that predated magnetic tape. After a year of searching, she managed to track down someone with the equipment to play it.

What she finally heard was a bootleg recording of her father singing a live performance in 1949. It was the first time she had ever heard him perform in front of a live audience. He had developed Huntington's chorea and stopped performing when she was a child, and she thought he had never been recorded live.

Woody Guthrie was an American folk singer and songwriter, known for songs like "This Land is Your Land," "Pretty Boy Floyd," and "Hard, Ain't It Hard." He died in 1967.

So she was determined to preserve the recording. For the first step, she and a team of engineers transferred it into digital format. It was a hair-raising experience. "The wire was really flimsy," says Jamie Howarth, a sound engineer on the job. "It was frustratingly, maddeningly fragile." It snapped over and over, and with every snap, a moment of the recording was lost. And when it didn't snap, it kinked and snarled.

After a 36-hour session, Guthrie and the engineers listened to the recording they produced. The pitch rose and fell independent of Guthrie's singing. They could hear him telling long stories, but only every few words were intelligible. The wire had stretched in places, slowing the recording down. The kinks produced moments of silence.

Howarth is the head of a company that specializes in restoring old analog recordings. If a tape slows down for any reason either during recording or playback, it lowers the pitch and stretches the sound out longer. If it speeds up, the pitch goes higher and the sound goes faster. Howarth had found that

slight speed variations occur even in modern recording equipment, creating slight distortions that sound like "wow-wow" or a flutter.

Sound File: Vivaldi Clip 1

This 50-second recording of the NBC Symphony Orchestra playing "Vivaldi Concerto for Orchestra and Two Violins" in 1955 is extremely distorted with a fast flutter and "wow" dips that are painful to listen to.
J. Howarth / Plangent Processes

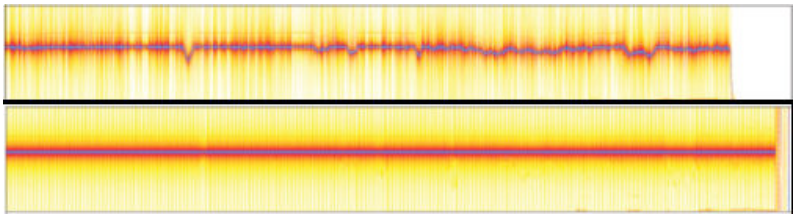
Fortunately, math can help. Howarth had developed algorithms to correct these recordings. He looks for extraneous sounds, like an air conditioner or fan in the background that creates a rhythmic sound. Instead of simply removing these sounds, he uses them as a clock, a kind of built-in foot-beat in the recording that tells him what the true timing should be. When a recording is made, this background rhythm is even. But when it's played back, it speeds up and slows down in perfect timing with the errors in the recording. That allows Howarth to adjust the timing of the recording to make it much more similar to the original sound.

Sound File: Vivaldi Clip 2

This is the same recording after Howarth's corrections.
J. Howarth / Plangent Processes

When Howarth isn't lucky enough to find a rhythmic background noise, he has another technique. He has found that all analog recordings contain a sort of rhythmic buzz at a specific frequency way above human hearing. This buzz can substitute for a background fan.

Howarth had successfully used these techniques to restore other old recordings, like the film soundtracks for *Oklahoma!* and *Close Encounters of the Third Kind*. But the Guthrie recording was such a mess that it forced him to develop new techniques. He turned to Kevin Short, a mathematician at the University of New Hampshire who had done work on signal processing for sound compression.



To test his algorithms, Howarth whapped a pencil eraser against the transport of a tape player during the recording of a single, steady tone, disrupting its even motion. The top sonogram shows the recorded pitch varying wildly with the disruption. He then corrected the recording using his algorithms and removed the distortion entirely, producing the bottom sonogram.
J. Howarth / Plangent Processes

The team discovered the many ways that wire makes a lousy material for sound recording. One problem is that wire's round. When the wire kinked, it would twist out of position and the head would no longer be reading the proper side of the wire. The machine still read the low and medium frequencies, but the very high frequency sounds dropped out—including the signal Howarth used as his foot-beat.

Short developed techniques to interpolate the missing information. "We could actually pick up a hum from the Con Edison power supplies," Short says. "It's a pretty nasty noise." Because that hum was lower frequency, it remained even in the twisted sections. Short also brought in more sophisticated techniques to shift the pitches once the algorithm had identified what needed to be done.

"When it was done, we were all just awed by this recording," Howarth says. "It was miraculous." Despite all the difficulties in the process, the wire recording was in many ways surprisingly good. "It sounds really, really, really good for its time," he says.

Sound File: Guthrie Clip 1—Before processing

Sound File: Guthrie Clip 2—After processing

To hear a sample of the recording, before and after processing, click on the sound file links above.

The restored recording was released last September and was almost immediately nominated for a Grammy. The award ceremony will be broadcast

Feb. 10.

If you would like to comment on this article, please see the blog version.

References and sources for this article

References:

Guthrie, W. 2007. *The Live Wire: Woody Guthrie in Performance—1949*. Woody Guthrie Foundation. Available for purchase at http://woodyguthrie.org/mm5/merchant.mvc.

Kevin Short's website is at www.math.unh.edu/~kmshort/.

Plangent Processes has a website with many more examples of their work at www.plangentprocesses.com/.

The full list of Grammy award nominations is at www.grammy.com/GRAMMY_Awards/.

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