

COUNTERINTUITIVE ESTIMATING STATISTICAL PROPERTIES

WITH ANY SAFETY-CRITICAL control system it is important to determine change or failure. Associate Professor Jeff Burl and his research team have written algorithms that can do just that, fast, even with suboptimal data.

Burl has conducted three failure analysis studies of late, all inspired by engine control. He has developed new schemes for parameter estimation and system burst change detection that utilize the system's Time Frequency Representation (TFR). The



Jeff Burl

TFR is a transfer function analog based on the wavelet transform, not the usual Fourier transform. Is your model changing over time? If so, wavelets do a better job of tracking changes than other transforms, notes Burl.

"The disadvantage of using wavelets is that they increase the amount of computation required," he adds. "This is a problem for lots of applications, and specifically for engine

applications. Engine development typically takes place over a multi-year timeframe. Computers age throughout the process, and after a few years they are considered slow by today's standards. Engine control computers are basically less-capable machines that are attempting to do a lot. So, an important question is: How do we reduce the computational burden? The key is to use only part of the data—the most important part."

Oddly enough, Burl has found that adding more data to an estimator doesn't always help. "It's counterintuitive. If a piece of data has noise, and very little info, you can actually do worse with more," he says,

In particular, when it comes to parameter estimation, if you *know* the statistical properties of the data, then more data always improves your performance. But if you have to *estimate* the statistical properties, because of errors in the estimates you'll do better for a while—but then you'll do worse. "

In engine applications, errors in the statistics of the data are especially common. "The way to achieve a smoother-running engine is data driven, but testing 500 engine cycles can be very expensive, especially when tests are required in many different scenarios, such as with different fuels, in different weather conditions, etc.," Burl explains.

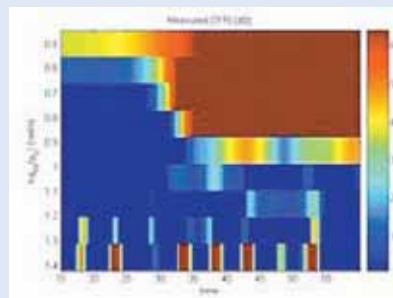
"There is such a premium on reliability in the auto industry," he adds. "By necessity, auto engineers must use very proven algorithms, so it takes a while for new methods to be applied. Our algorithm, however, is widely applicable—it can be used for engine applications and other applications, too, because of its ability to do more with less."

Burl's algorithm could be potentially applied in numerous areas—from missiles, robotics, and biomedical applications to engine mechanics. "It's useful for any time-variant device," he notes. "It can be applied in a device that is used to measure a heartbeat or warn of a potential change in blood gases. Another application could be the assessment of military battle damage. If there's a failure in a system component, you can use this algorithm to find out—quickly—and modify it."

Burl and his research team have managed to add capability without adding too much computational burden. "Our goal is always to reduce computational time." One way to do that: "Don't use all the data. It turns out that using all the data sometimes gives worse results. Our technique orders data from best to worst."

DETECTING SYSTEM BURST CHANGES

Jeff Burl has developed a new scheme to detect system burst changes that utilizes the system's Time Frequency Representation (TFR). The computational workload of this detection algorithm is small because of its concise system representation, as well as the fact that no parameter identification is required prior to burst detection. It is suitable for computationally restricted environments.



TFR magnitude for a motor control system experiencing a tachometer failure.