Eliminating mechanical vibrations leads to better performing mechatronic systems

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For precision engineering systems, such as CD and DVD players, anti lock braking systems and computer hard disk drives, vibration can significantly affect performance. Now, A*STAR engineers have developed an efficient and reliable method for eliminating a major source of vibration.

Vibration is a significant destabilizing source that can seriously degrade the operation, lessen the working life, and, in some cases, lead to catastrophic failure of mechatronic—integrated mechanical, electrical and computer systems—devices. Produced internally from sources of noise such as motors, bearings and other moving parts as well as from electrical noise, unwanted vibration should be eliminated or compensated for.

Mechanical resonant modes—frequencies that match those of one or more of a system's mechanical components, the effects of which can be felt when a part of a car begins to vibrate at a particular speed—whose natural frequencies are above a specific frequency for a sampled-data mechanical system, referred to as the Nyquist frequency, are reflected back at low frequencies and become indistinguishable from the output signal. Such signals are tricky to identify and therefore not easily extracted.

Yan Weili and colleagues at the A*STAR Data Storage Institute have developed a powerful mathematical model that identifies mechanical resonance modes above the Nyquist frequency that lead to vibration, so they can potentially be eliminated, leading to better performing mechatronic systems.

"Our method can potentially be implemented on mechatronic systems without the requirement for any external equipment, such as a laser Doppler vibrometer, or external excitation signals," says Yan. "It is less time-consuming and not as computation-heavy as analog methods, and can be applied to ultra-high performance mechatronic systems and advanced motion control for nano-positioning systems."

The researchers used a mathematical method based on statistical modeling, known as a polynomial transformation technique-based recursive least-squares algorithm, to first generate a mixed-rate model using fast sample rate inputs and slow-sample rate outputs that identifies the mechanical resonances beyond the Nyquist frequency, and then to derive a fast-rate model involving fast sample-rate inputs and fast sample-rate outputs from which the unwanted frequencies can be extracted.

To evaluate their approach, the researchers used a voice coil motor actuator in a commercial hard disk drive—a typical mechatronic component that contains many mechanical resonant modes—and used simulation and experimentation to verify its effectiveness.

"The outputs from the simulation and experimentation were in good agreement, confirming that the parametric identification approach is efficient, consistent, and can be realized online," says Yan.

More information: Chee Khiang Pang et al. Multirate Identification of Mechanical Resonances Beyond the Nyquist Frequency in High-Performance Mechatronic Systems, *IEEE Transactions on Systems, Man, and Cybernetics: Systems* (2016). DOI: 10.1109/TSMC.2015.2448054

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