Compressed MRI: image manipulation scans lab-on-a-chip

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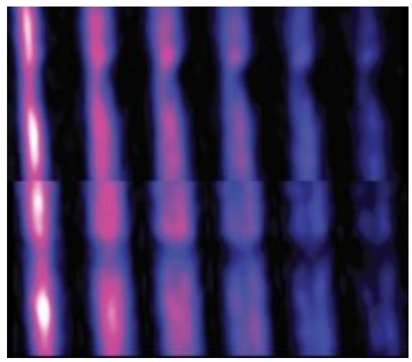
MRI a million times better



Remotely detected MRI images

Remote instrumentation and image compression allowed US chemists to utilise NMR/MRI to image materials flowing through a "lab-on-a-chip" device and to zoom in on microscopic objects of particular interest with unprecedented spatial and time resolution.

Scientists inevitably strive for better and faster results and for studies of the structure of materials at the atomic and molecular scales, nuclear magnetic resonance (NMR) spectroscopy and its sibling magnetic resonance imaging (MRI) are developing apace to keep up with demands. Now, in work supported by the US Department of Energy, the Office of Science and through a donation by the Agilent Technologies Foundation, a US team looks set to give NMR/MRI results a million-fold boost.

Chemist Alexander Pines and his colleagues at the Lawrence Berkeley National Laboratory (Berkeley Lab) and the University of California (UC) at Berkeley have combined remote instrumentation, image compression algorithms akin to those used for web-graphics in the JPEG format, as well as several other enhancements, have used a hybrid approach to NMR and MRI to obtain images of materials flowing through microfluidic "lab-on-a-chip" devices and to zoom in on microscopic objects within the system that are of particular interest. The work offers unprecedented spatial and time resolutions.

"What excites me most about this new methodology is the possibility of a mobile, chip-based NMR/MRI platform for microfluidic analysis. Who knows? This might turn out to be useful for chemistry and biomedicine," says Pines.

Zooming MRI

The team, which includes Pines team members Vikram Bajaj, Jeffrey Paulsen, now working at Schlumberger-Doll Research and Elad Harel currently at the University of Chicago, have used the technique

to measure flow dynamics and other characteristics of a microfluidic device with incredible sensitivity.
"We have been able to conclusively demonstrate the ability to record microscopic images of flowing macroscopic objects without loss of sensitivity, something that is impossible in conventional MRI," says Bajaj. "We were also able to illustrate how MRI can be used to measure flow dynamics quantitatively and with high spatial resolution in real microfluidic devices. The spatial resolution we achieved is sufficient to capture the results of hundreds or thousands of parallel assays on a microfluidic device. Furthermore, we recorded these images approximately one million times faster than could be done with a conventional MRI experiment. This means that experiments which would have taken years to complete, hence were impractical to consider, would now be possible."

While MRI is well known as an advanced imaging technique used by the medical profession for non-invasive diagnoses, the fact that it also uses no ionizing radiation means it can be used to image molecular systems and devices that would be susceptible to radiation damage. Conventional MRI scanners use an enormous "doughnut" shaped machine that fills an entire room and is costly to purchase, operate and maintain. Pines and his colleagues wanted to remedy that situation for non-medical applications of MRI and have made many important advances in the miniaturisation of the technology to make it more compact, portable and cheaper.

Portability, that's the beauty of decoupling

The team has previously managed to decouple the resonance signal encoding from signal detection processes and so made remote NMR/MRI possible. This almost instantaneously opened up the possibility of applying the technology to lab-on-a-chip microfluidic assays of gases and liquids. As such, the Pines group has set research on the path to portable chemical and biomedical analysis using NMR/MRI.
"Our goal is to develop NMR/MRI appliances for portable chemical analysis of complex mixtures, including blood, urine, and saliva," adds Bajaj. "Ultimately, we would like to make it possible to use NMR/MRI in point of care clinical analysis."

In the latest research, Pines and Bajaj and their co-authors describe how to use MRI technology to study microscopic flow through microfluidic or biological channels, or through porous materials. The key to success is the integration of several new elements into their remote NMR/MRI configuration. This included the fabrication of microsolenoid MRI probes with demountable microfluidic device holders, the design of remote MRI sequences for spatial encoding in the presence of motion, as well as for velocimetric measurements, and the use of a JPEG-style compressive sampling algorithms for accelerated image encoding. JPEG, Joint Photographic Experts

Group, image compression is a "lossy" method for reducing the size on disk of a photographic or other image.

Compressed and lost

The JPEG compression system works by recoding the file so that similar pixels are essentially marked as duplicates rather than their complete data being stored. The system can compress files of several megabytes to mere hundreds of kilobytes. There is loss of data, but choosing an appropriate compression ratio allows for a compromise between file size and quality. The reverse, decompression process, can also be carried out to yield either the highest quality image possible after compression or for speedier rendering a lower quality image can be displayed without further data loss to the original compressed JPEG.
"The combination of remote NMR/MRI methods with these new elements spectroscopically mimics the implantation of a coil around a microscopic feature of interest and allows us to zoom in on the microscopic details of microfluidic flow dynamics in three spatial dimensions," explains Bajaj. "The mechanism of remote detection is analogous to that of a magnetic recording tape on which complex data are first encoded and later read out by a single stationary detector as the tape advances."

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- **Science, 2010, 1078-1081**: "Zooming in on Microscopic Flow by Remotely Detected MRI"

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