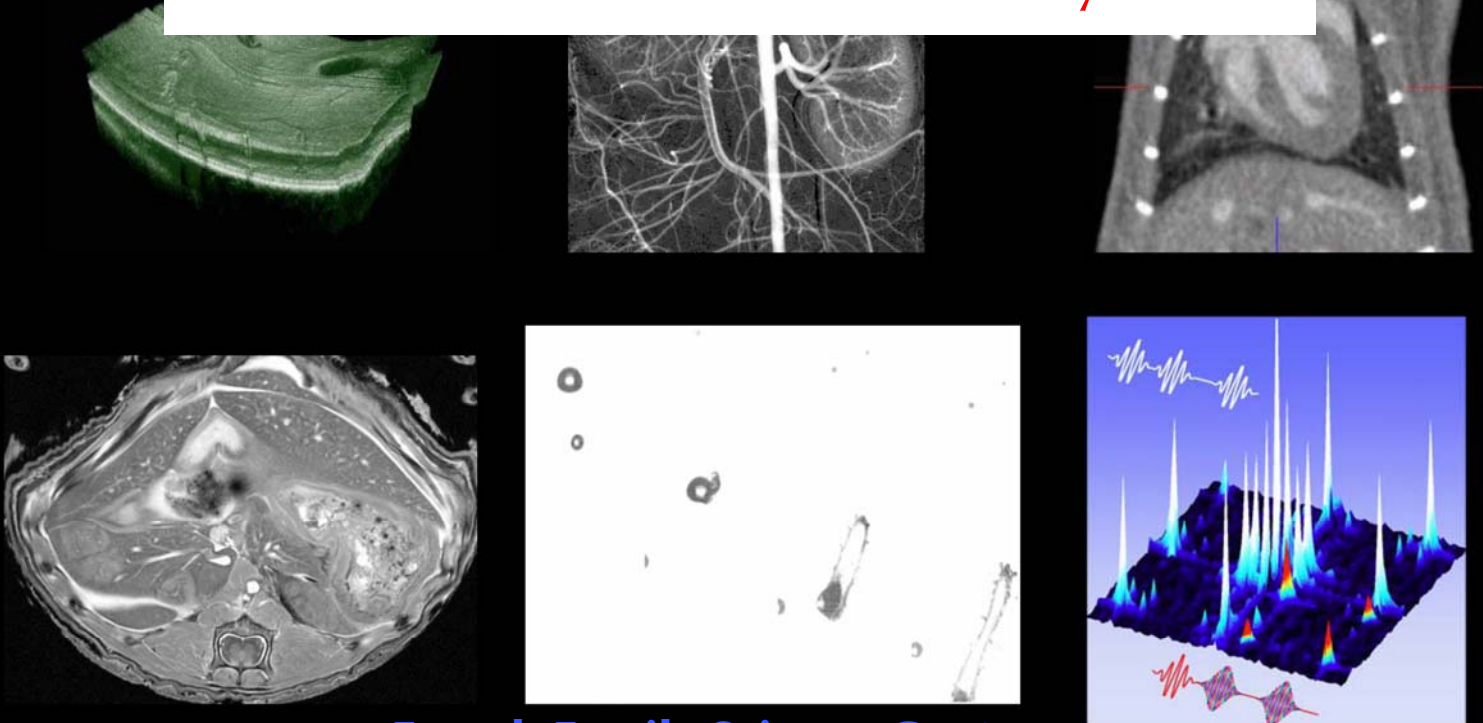


Center for Molecular and Biomolecular Imaging
Duke University

From Imaging to Understanding:
Visualization and Smart Analysis



French Family Science Center
Duke University
December 12-13, 2010

Duke University

Center for Molecular and Biomolecular Imaging

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December 12, 2010

Welcome to the "Htqo "K ci lpi "vq" Wpf gtucpf lpi <"Xkuwrk cvkqp" cpf "Uo ctv" Cpcn{ uki" meeting," which is the annual meeting of the Center for Molecular and Biomolecular Imaging at Duke. The meeting takes place in the French Family Science Center (dedicated November 2007), which I think you will agree provides an outstanding venue for research and education.

"Vj g"4232" cppwcn" o ggkpi "y kn" hqewu" qp" vj g" kpgtf kuek r pct { "kpgmgewcn" ej cmgi gu cuqekcvf "y kj "gzvcevkpi "wughwi" lphqto cvkqp" Htqo "tcy "f cv" k" k ci lpi " cpf "ur gestqueqr { 0 Vj g" o clqt" k kcvkp" qh" o qf gtp" k ci lpi "ku" tctgn{ "uki pcn" k'ku" eqpvtcu<" utwewtg" eqttgrvgu" r qqtn{ y kj "hpevkqp. "cpf "qhvgp" vj g" k r qtcvpv" f gcknu" k" cp" k ci g" qt" ur gestwo "ctg" qduewtgf "d { "pqkug. f { pco le" tcpi g. "qdxkqu" dw' wpo r qtcvpv" hgcwtgu. "qt" vj g" t gultevkqpu" eqpxgpvkpcn" tgeqpustvevkqp vqqu" uwej "cu" Hqwtlgt "tcpuhqto u" k r qug" qp" dcpf y kf vj "cpf "ces wkukqp" k" g0" Vj g" i qcn" qh" vj ku cppwcn" o ggkpi "ku" vq" dtlpi "qi gj gt "uelgpvkuu" Htqo "hgrf u" tcpi lpi "Htqo "r wtg" o cvj go cveu" vq enplecn" tcf kmqi { "cpf "ctw qtm" xcrlf cvkqp. "k" qtf gt "vq" j ki j v" vj g" wpf gtn{ lpi "r tlpek r ngu" cpf qr r qtwpkkgu" k" vj ku" f kuek r kpg0

CMBI is a Provost-level organization which transcends school boundaries at Duke (interconnecting Trinity College of Arts and Sciences, the Pratt School of Engineering, the Medical School, and the Nicholas School of the Environment) to support the transformative and inherently interdisciplinary nature of modern imaging science. This has a natural connection with one of Duke's greatest strengths, which can best be appreciated on *Google Maps*. If you locate the French Family Science center at 124 Science Drive, and go to the 200 foot scale, you will find all of physics, biology, chemistry, engineering, and computer science, and virtually all of the basic science buildings of the medical school. This extremely unusual proximity can, and does, foster strong connections between departments. To support this very broad field, our meetings have widely varying themes and foci. The preceding meeting (F ge04232), for example, focused on vj g" Htqpvgt" qh" rugt" k ci lpi . "cpf "y cu" j grf "lqkpv{ "y kj "Eqj gtgpv" u" Uqwj gcuv" Tgi kpcn" Wntchuv o ggkpi 0

Vj gug" o ggkpi u" f q" not happen" spontaneously. I am very grateful for the eqpvkpvkpi efforts of "Mike Conti " (CMBI), "hqt" j gr lpi "vq" qti cpk g" vj g" o ggkpi . "cpf "vq" vj g" EO DK" uggtkpi " "eqo o kvgg" hqt" vj gk" vj qwi j w' cpf "i wkf cpeg0

Warren S. Warren
Director, Center for Molecular and Biomolecular Imaging
Duke University



From Imaging to Understanding: Visualization and Smart Analysis

December 12-13, 2010, French Family Science Center

Schedule of Events:

Sunday, December 12, 2010

5:00-6:00 Registration and Poster Setup

6:00-7:00 Invited session

6:00 Robert Calderbank, Duke University (Mathematics/Computer Science)

6:25 Kamil Ugurbil, University of Minnesota (Center for Magnetic Resonance Research)

7:00-9:00 Poster session and Reception

Monday, December 13, 2010

8:30-9:00 Breakfast

9:00-12:00 Morning Session

9:00 Geoff Rubin, Duke University (Radiology)

9:25 Stephen Pizer, UNC (Medical Image Display and Analysis Group)

10:00 A. J. Shaka, University of California Irvine (Chemistry)

10:35 Break

10:45 Sina Farsiu, Duke University (Biomedical Engineering)

11:10 Quetz Magaña (Spectralysis, LLC)

11:45 Rachael Brady, Duke University (Visualization Technology Group)

12:15-1:30 Lunch and Poster Session

1:30-4:30 Afternoon Session

1:30 Bernhard Blümich, Aachen University, Germany (Materials Science)

2:05 G. Allan Johnson, Duke University (Center for in vivo Microscopy)

2:30 Montserrat Fuentes, N.C. State University (Statistics)

3:05 Tom Matthews, Duke University (Chemistry)

3:30 Paul Segars, Duke University (Radiology)

3:55 Tamara Branca, Duke University (CMBI)

Hidden Markov Trees for Image Processing



Robert Calderbank
Dean of Natural Sciences
Duke University

In addition to being the dean of natural sciences, Robert Calderbank is a full professor in the department of computer science, with joint appointments in mathematics and electrical engineering.

Professor Calderbank joined Duke in 2010. He was previously director of the Program in Applied and Computational Mathematics at Princeton University, as well as a professor of electrical engineering and mathematics. Before joining Princeton in 2004, Professor Calderbank was vice president for research at AT&T, where he was responsible for one of the first research labs whose primary focus was data at a massive scale, for such applications as networking, information and software, speech and multimedia services.

Abstract:

There has been increasing interest in the use of image processing tools applied to the analysis of art. In this talk, we will focus on the use of wavelet representations and Hidden Markov Trees, which provide a multiscale analysis of an image by separating its features according to the level of detail involved. We will show applications in analysis of style and period for paintings by Vincent Van Gogh and Goossen Van Der Weyden. We will also present initial results for applications of Hidden Markov Trees to the detection of melanoma in skin sample images.

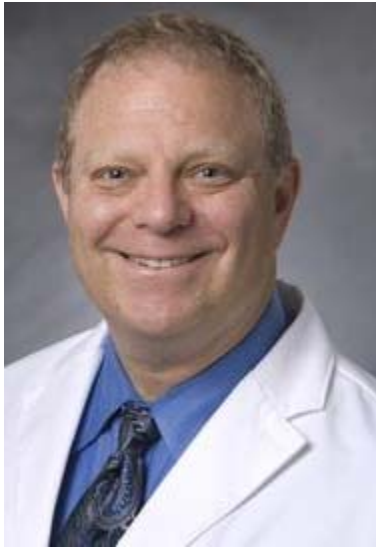
From Imaging to Understanding: Visualization and Smart Analysis



Kamil Ugurbil
Director, Center for Magnetic Resonance Research
Professor of Biochemistry, Radiology & Medicine
University of Minnesota

The primary focus of the ongoing research activity at the Center for Magnetic Resonance Research (CMRR) is to develop techniques that will permit novel use of high field magnetic resonance (MR) spectroscopy and imaging, and apply these techniques to biomedical questions relevant to basic physiological research and clinical medicine. Among the areas targeted for human MR studies, the most important and prominent is neurophysiology based on non-invasive functional imaging in the brain, high-resolution and/or high contrast imaging of neuroanatomy, imaging of perfusion, and finally spectroscopic studies of metabolism. This laboratory has pioneered the development of non-invasive functional imaging in the human brain using magnetic resonance techniques and endogenous deoxyhemoglobin as an intrinsic contrast agent.

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Geoff Rubin, M.D.
Chair, Department of Radiology
Duke University

Dr. Rubin is the new Chair of the Department of Radiology. He comes to Duke after serving as professor of radiology at Stanford University School of Medicine, where he was also Chief of Cardiovascular Imaging, and Medical Director of the 3-D Laboratory in the department of radiology. He was also Vice Chief of Staff, Stanford Hospitals, Associate Dean for Clinical Affairs for the Stanford University School of Medicine, and Associate Director of the Cardiovascular Institute at Stanford.

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3D Visualization in Radiation Treatment Planning via Object-Relative Coordinates



Stephen Pizer

Professor of Computer Science, Radiation Oncology, Radiology &
Biomedical Engineering
University of North Carolina at Chapel Hill

Professor Pizer heads the multidepartmental Medical Image Display and Analysis Group (MIDAG) and co-leads the Department of Computer Science's Graphics and Image Laboratory. His research, focused since 1962 on medical image processing and display, covers image analysis, human vision, interactive 3D graphics, and contrast enhancement. The image and analysis display techniques have especially involved object extraction, image registration, and shape measurement based on medial models of object shape.

Dr. Pizer will be presenting on his work with Derek Merck, Ilknur Kabul, and Julian G. Rosenman.

Non-standard NMR Analysis



A. J. Shaka
Professor of Chemistry
University of California, Irvine

The Shaka laboratory group's main interest is in improving NMR techniques and applying them to high field solution experiments from small molecules to very large proteins. Ongoing collaborations with structural biologists, organic chemists, crystallographers, and theorists search for improved methods to identify and characterize molecular structure and dynamics in solution.

Abstract:

We usually compute nuclear magnetic resonance (NMR) spectra by a discrete Fourier transform, taking a transient time-domain signal (free-induction decay) as input and converting it into a complex spectrum of amplitude versus frequency. The linearity of the FT means that noise is properly displayed, and the conservative nature of the time-frequency uncertainty principle gives a spectrum in which resolution (splittings and line widths) is always coarser than the true peaks. As the FT requires minimum data records regardless of the inherent signal-to-noise ratio (SNR), other methods that can capitalize on an assumed model of the NMR data and attempt to extract parameters of the model in cases of good SNR have become fashionable. The idea is to get to a usable spectrum in far less instrument time, using far more computer time. We have actively explored a particular variant in this race for speed and accuracy, called the Filter Diagonalization Method. In this talk, the performance of FDM will be compared and contrasted with that of the FT and other methods, and some new and rather surprising conclusions about optimum sampling in the time domain will be highlighted.

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Smart Acquisition, Restoration, and Automated Analysis of Clinical Images



Sina Farsiu

Assistant Professor, Departments of Ophthalmology and
Biomedical Engineering
Duke University

Professor Farsiu is the director of the Vision and Image Processing (VIP) Laboratory. They investigate how to improve early diagnostic methods and find new imaging biomarkers of ocular diseases. The laboratory is also working on efficient signal processing based methods to overcome the theoretical and practical limitations that constrain the achievable resolution of any imaging device. He is also an Associate Editor for the IEEE

Transactions on Image Processing.

Abstract:

On the quest to gather useful information from medical images through hardware design improvements, one quickly runs into the problem of diminishing returns. Not only do theoretical and practical limitations constrain the achievable quality of any imaging device, but the optical components necessary to capture very high-quality images become prohibitively expensive for many practical applications. On another front, the avalanche of data created by such imaging systems is often too large, costly, or time-consuming to be fully analyzed by clinicians. In this presentation, we will address the issue of generating high-quality imagery from systems having lower-quality imaging detectors, and introduce our image analysis tools capable of providing quantitative measurements of imaging biomarkers of the onset and progression of ocular diseases with higher reliability than current manual analysis techniques.

Automated Analysis of Spectra and its Applications



Quetzalcoatl Magaña
President, Spectralysis, LLC

Dr. Magaña (PhD, Chemical Engineering, Case Western Reserve University) has developed high-functioning scientific software programs and is presently concentrating on automatic analysis algorithms for a variety of spectroscopies and applications.

Abstract:

Spectralysis, LLC has developed an original spectroscopic peak finding and fitting algorithm. The method is based on a novel, sophisticated algorithm for calculating the spectral baseline. The software analyzes spectra by identifying peaks and determining their characteristics, i.e. position, peak height, full width at half maximum. The software is also capable of analyzing thousands of comparable samples automatically, without human interaction (batch processing), and then performing data model analysis on the results. The software has been applied in several spectroscopic disciplines, including photoluminescence, Raman, and FTIR in mineralogy, XPS in material sciences, and visible in astronomy. The method is believed to be applicable to many other spectroscopic fields and applications, such as chemometric analysis, biological sciences, food and pharmaceuticals. It is hoped that the method could be applicable over the entire electromagnetic spectrum, and extendable to resonance spectroscopy, mass spectrometry and chromatography.

From Imaging to Understanding: Visualization and Smart Analysis

Including Visual Analysis in Research



Rachael Brady
Director, Visualization Technology Group
Duke University

Rachael Brady is a senior research scientist with appointments in the Pratt School of Engineering, Computer Science, and Visual Studies. With an educational background in Mathematics, Physics and Statistics, she worked on signal detection and image processing algorithms at Jet Propulsion Lab and turned to biomedical visualization at Illinois' National Center for Supercomputing Applications. Rachael currently directs Duke University's Visualization Technology Group, which promotes the use of visualization and virtual reality technologies when doing basic research and data analysis, teaching, demonstrating and publishing.

Abstract:

Just like writing a paper, the act of visualizing one's data requires the scientist to stop and reflect on the questions they wish to ask of their data. Sometimes the resulting analysis is straight forward, such as calculating a histogram, but sometimes the data analysis requires more sophisticated methods drawn from fields such as statistics, image processing, computer vision, computational geometry, or machine learning. In this talk I will introduce the efforts of the Visualization Technology Group to provide expertise, software and display technologies for basic visualization needs. But more importantly, we seek to collaborate with researchers (both imaging scientists and analysis scientists) to develop good visual analysis tools which will help a researcher ask "What if?" or "Compared to What?" questions.

NMR and Motion



Bernhard Blümich
Professor of Macromolecular Chemistry
RWTH Aachen University

Professor Blümich's team is developing NMR methods and applications in material science and chemical engineering. Their research work focuses on NMR methods and hardware guided by applications to polymers and elastomers, fluid transport in chemical engineering models and geological core samples, and noninvasive product and process control in a manufacturing environment.

Abstract:

Two aspects of motion are addressed in the context of NMR. The first one relates to the analysis of mass transport, where NMR provides unique insight at different length scales. The second one relates to mobile NMR, that is, to moving the NMR machine to the object or phenomenon of interest. Ultrafast velocity-vector imaging has been developed and applied to study internal motion in fluid drops levitated in a counter-flowing fluid of higher density. Sensitivity demands the use of high-field NMR with large magnets and small bore holes, although it would be more desirable to employ the NMR machine as a sensor in an operational setting. The realization of this vision has become much closer today since the development of desktop tomographs, small spectroscopy systems, and stray-field relaxometers which use care-free permanent magnets. The sensitivity loss from measuring at low field can be more than just recovered in selected cases by hyper-polarization and novel detection schemes. We find that magnetization transfer by catalyst-mediated molecular contact is a promising method that bears the potential for trace analysis by low-field spectroscopy. Recent advances of mobile and low-field NMR are summarized with reference to inline quality control, analysis of skin, and characterization of objects of cultural heritage.

The Multidimensional Mouse Brain



G. Allan Johnson
Director, Center for In Vivo Microscopy*
Duke University

Professor Johnson has joint appointments in the departments of Radiology, Biomedical Engineering, and Physics. His research focuses on magnetic resonance histology (MRH), the application of MR microscopy to the study of tissue architecture. He is currently the director of Duke University's Center for In Vivo Microscopy, a National Resource dedicated to the development of novel preclinical imaging strategies and application of those methods to important biomedical questions. The CIVM houses five state of the art MRI systems, microCT, microXRay, micro ultrasound and optical imaging all scaled for small animal imaging. The CIVM is

Abstract:

The mouse brain is a focus of interest for a wide range of basic scientists in neuroscience, genetics, and drug discovery. MRI can provide a wide range of insight into the organ from structure to function. The mouse @ 25 gm is nearly 3000 times smaller than the human so the resolution must be at least 3000X higher. The technical challenges of imaging at microscopic resolution are formidable. But the rewards are great. This talk will focus on some of the novel strategies developed to achieve spatial resolution up to six orders of magnitude higher than that of a routine clinical MRI and some of the exciting applications that these advances have enabled.

* Support from NCRR and NCI (P41 05959/U24 CA 092656)

Statistical Analysis of Gridded Areal Data: Applications to Air Pollution Mapping



Montserrat Fuentes
Professor of Statistics
North Carolina State University

Professor Fuentes's research focuses on spatial-temporal models, spatial statistics, spectral methods, computational methods of large data sets, applications in climate and air quality modeling, impacts of air pollution on human health, oceanography, atmospheric and environmental science. Along with her position at NCSU, she is a visiting scientist with the Environmental Protection Agency's Atmospheric Modeling Division.

Abstract:

Constructing maps of dry deposition pollution levels is vital for air quality management, and presents statistical problems typical of many environmental and spatial applications. Ideally, such maps would be based on a dense network of monitoring stations, but this does not exist. Instead, there are two main sources of information for dry deposition levels in the United States: one is pollution measurements at a sparse set of about 50 monitoring stations called CASTNet, and the other is gridded areal images obtained as output of regional scale air quality models, called CMAQ. A related problem is the evaluation of these numerical models for air quality applications, which is crucial for control strategy selection. We develop formal statistical methods for combining sources of information with different spatial resolutions and for the evaluation and bias adjustment of spatial images obtained from numerical models or satellite data.

We specify a simple statistical model for both sources of data (images and ground observations) in terms of the unobserved ground truth, and we estimate the model in a Bayesian way. This provides improved spatial prediction via the posterior distribution of the ground truth, and enables us to remove the bias in the spatial images (output of CMAQ). We apply our methods to data on SO₂ concentrations, and we obtain high-resolution SO₂ images by combining observed data with model output. We also conclude that the numerical models perform worse in areas closer to power plants, where the SO₂ values are overestimated by the deterministic models.

Pump-Probe Imaging Differentiates Melanoma From Melanocytic Nevus



Thomas Matthews
Doctoral Candidate
Duke University

Tom's research has focused on developing a pump-probe imaging technique based on transient absorption spectroscopy which can directly capture the microscopic distributions of the two forms of melanin found in human skin: eumelanin and pheomelanin. Examining thin slices of human pigmented lesions, his lab group has found substantial architectural and chemical changes between malignant melanomas and benign, dysplastic nevi (moles). Melanomas were found to contain more eumelanin and were more chemically heterogeneous than benign lesions.

Abstract:

Diagnosis of melanoma is clinically challenging; the accuracy of visual inspection by dermatologists is highly variable and heavily weighted towards false positives, and even the current gold standard of biopsy results in varying diagnoses amongst pathologists. Melanoma presents a promising optical target because suspicious lesions are accessible and the two dominant types of melanin (eumelanin and pheomelanin) provide a specific, intrinsic molecular contrast. We have developed pump-probe spectroscopy based on modulation transfer which allows direct imaging of the microscopic distribution of eumelanin and pheomelanin in human pigmented lesions of the skin. Our initial results show a marked difference in the chemical variety of melanin from non-malignant nevi to melanoma as well as a number of substantial architectural differences, creating the basis for a both highly sensitive and specific diagnostic method.

Realistic Computational Phantoms for Imaging Research



Paul Segars
Associate Professor of Radiology
Duke University

Professor Segars's research involves the use of computer-generated phantoms and simulation techniques to investigate and optimize medical imaging systems and methods. Medical imaging simulation involves virtual experiments carried out entirely on the computer using computational models for the patients as well as the imaging devices. Simulation is a powerful tool for characterizing, evaluating, and optimizing medical imaging systems.

Abstract:

We develop a series of realistic phantoms for multimodality imaging research. Highly detailed whole-body anatomies for the human and animal models including cardiac and respiratory functions are defined using non-uniform rational b-spline (NURBS) surfaces based on an analysis of imaging datasets. Combined with accurate models of the imaging process, the phantoms can produce realistic imaging data allowing a user to perform experiments that would be otherwise impractical using live subjects. Distributed to the research community, such a unique library of computational models has a widespread use in imaging research to quantitatively evaluate and improve imaging devices and image processing, analysis, and reconstruction techniques and to investigate the effects of anatomy and motion.

Nonlinear MR Imaging of Brown Fat



Rosa Tamara Branca
Assistant Research Professor of Chemistry
Duke University

Professor Branca's research focuses on magnetic resonance in obesity and cancer treatment, developing new diagnostic tools that will improve our understanding of the onset of these diseases and evaluating the effectiveness of proposed solutions. Her latest work has been the development of new NMR methods that help to assess, at the cellular level, adipose tissue composition and function, and to detect changes that occur in this tissue upon diet or drug intervention.

Abstract:

The spatial resolution limits of magnetic resonance imaging can be overcome by using non linear MR signal which is refocused from intermolecular dipolar –dipolar couplings. Because these couplings resolve sub-voxel details, this technique can be used to detect Brown Adipose Tissue (BAT), which recently has gained much attention as it is thought to have a large impact on long-term energy balance. Thanks to its capacity to burn calories, BAT could present an ideal target for obesity drugs. Despite its importance, this tissue is very hard to detect *in vivo* and to differentiate from the more abundant white adipose tissue. Partial volume effects, which arise from the limited spatial resolution available in magnetic resonance, limit MRI *in vivo* detection. Non linear MR uniquely delivers the capability to probe cellular structure, and we use it here to detect brown adipose tissue in small animals.