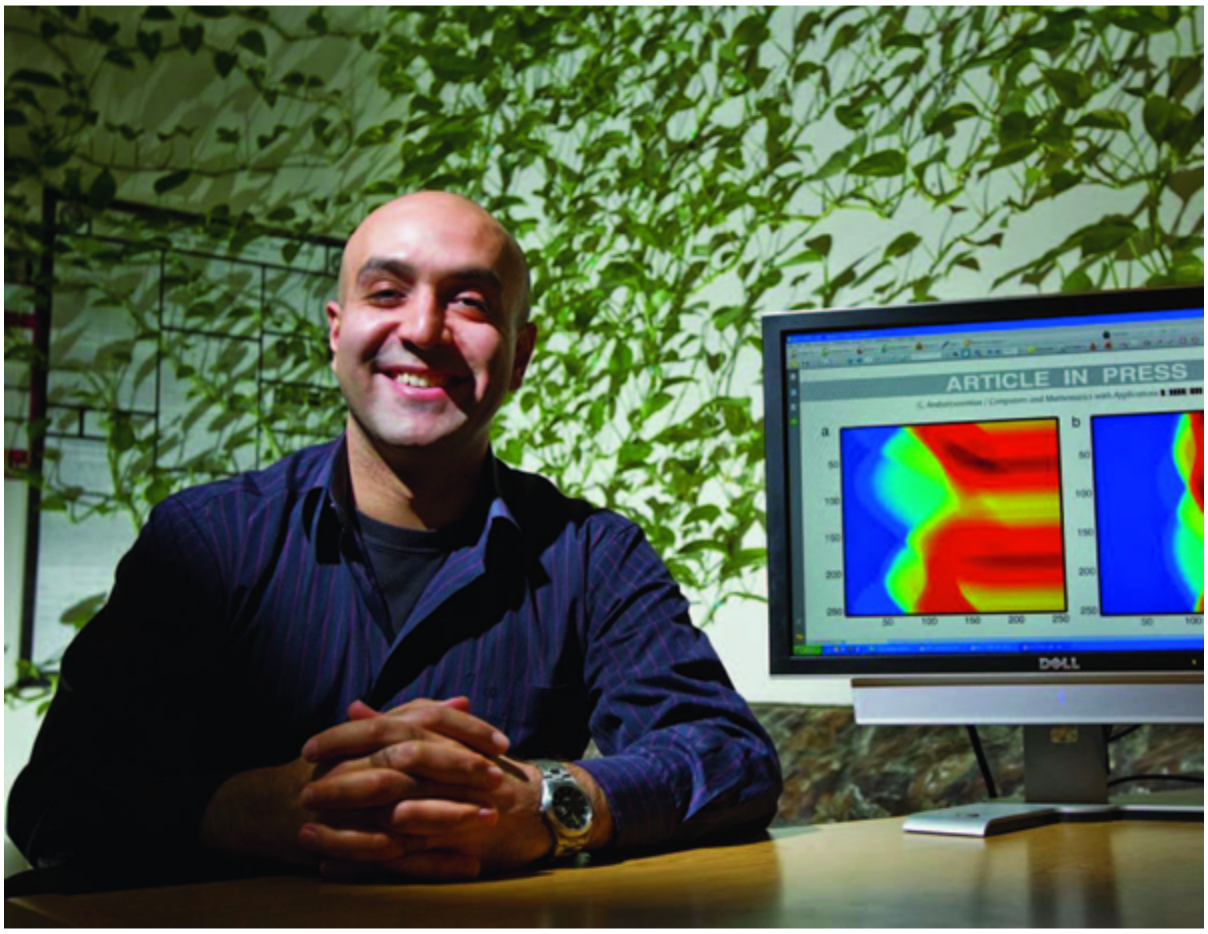
MAVERICK SCIENCE

The University of Texas at Arlington College of Science 2012-13



Ambartsoumian's research has the potential to save lives through better detection of diseases by imaging equipment.

Sharper image

Using mathematical models, Gaik Ambartsoumian is helping to improve the effectiveness of medical imaging technology

By Greg Pederson

Medical imaging - the process of creating pictures of the human body's interior for clinical purposes or medical science - has been invaluable in helping doctors diagnose and treat disease. Its capacity for early detection of malignant tumors has saved hundreds of thousands of lives.

Scientists can utilize mathematical models to seek answers to some of the problems created by medical imaging. This is exactly what Gaik Ambartsoumian, a UT Arlington assistant professor of mathematics, is doing. He has already done extensive research into mathematical problems of image reconstruction, and is currently involved in two funded projects in the field.

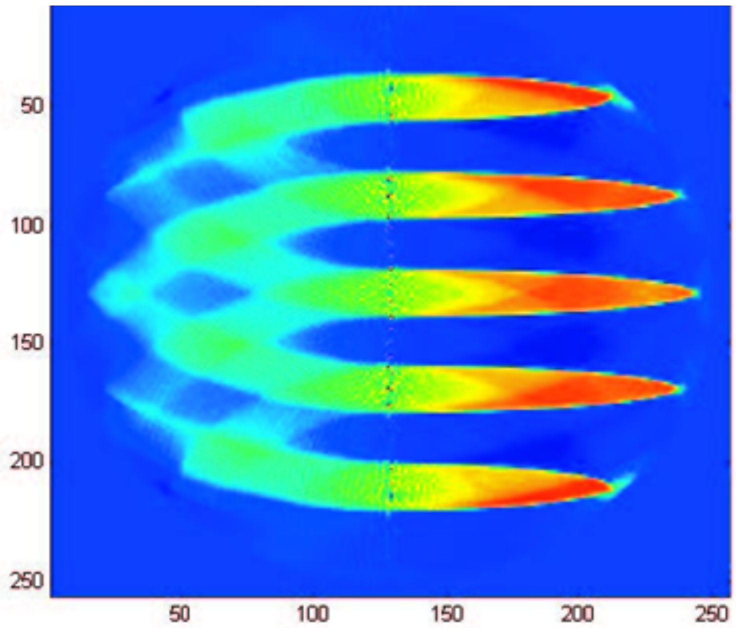
"Medical imaging has become an indispensable tool in modern healthcare both for diagnostics and for treatment monitoring of various diseases," Ambartsoumian said. "Early detection of cancer, made possible by various advanced imaging devices, is saving tens of thousands of lives every year, and we can certainly do better - by improving the quality of existing technologies, making the procedures more affordable, and eliminating potential side effects, such as exposure to ionizing radiation."

One of Ambartsoumian's current projects is being funded by a three-year, $175,899 grant by the National Science Foundation and involves the use of Radon transforms to assist in creating an image. Radon transforms map functions to their integrals along certain curves or surfaces. In many imaging procedures the data measured by scanning devices correspond to such integrals. The mathematical problem of creating an image from such data requires recovery of the function from its integrals, i.e. inversion of the Radon transform. Hence the study of these types of transforms and their properties are crucial in many image reconstruction problems.

A second project, focusing on image reconstruction problems in tomosynthesis, is funded by a three-year, $150,000 grant by the Norman Hackerman Advanced Research Program. Tomosynthesis is a method for performing high-resolution limited-angle tomography. Its primary use is in breast imaging, where it may offer better detection rates than standard mammography with little extra increase in radiation.

His recent research has been dedicated to the study of elliptical Radon transforms in near-field ultrasound tomography and in radars. A paper that he co-authored with Jan Boman, a professor at Stockholm University in Sweden; Todd Quinto, the Robinson Professor of Mathematics at Tufts University; and Venky Krishnan, a faculty member at the Tata Institute of Fundamental Research in Bangalore, India, will appear soon in the Contemporary Mathematics book series of the American Mathematical Society. In this work they analyzed the math behind a novel data acquisition method in ultrasound and developed algorithms for the problem. The study focused on a generalized Radon transform that had come up in research Ambartsoumian did with colleagues at UT Arlington and UT Southwestern Medical Center, which utilizes the latest in medical imaging equipment. He, Quinto, Krishnan and two other researchers also co-authored a journal article on radar imaging.

"I've known Gaik since he was in graduate school, and I am impressed with the depth and breadth of his research," Quinto said. "He has proven theorems that answer important questions in tomography, and he has developed algorithms for those problems. Along with colleagues in the U.S. and abroad, we are now coming to understand the mathematics behind so-called bistatic radar – when the radar transmitter and receiver follow different trajectories. Our final goal is to use this to develop better ways to collect and process radar data."



This image shows a numerical reconstruction of a crosssectional image of a simulated 3-dimensional object called Defrise phantom. The phantom consists of five thin ellipsoidal discs stacked along the same axis inside a sphere. The reconstruction is based on the inversion of the Spherical Radon Transform in the limited view setup, where the data is collected only from the right half of the sphere. Photo courtesy of Gaik Ambartsoumian.

Much of Ambartsoumian's earlier research has been dedicated to mathematical questions connected with the emerging medical imaging modalities of thermoacoustic (TAT) and photoacoustic (PAT) tomography. TAT and PAT tomography are widely considered to be among the most promising novel types of medical imaging. Both are hybrid imaging technologies, where the patient's body is irradiated by electromagnetic waves (microwaves in TAT and lasers in PAT), which heat up the body. The resulting thermal expansion of the tissue creates sound waves, which are measured by ultrasound microphones outside of the body.

These measurements are then used to recover the unknown function of electromagnetic energy absorption inside the patient's body, which in turn enables the reconstruction of PAT or TAT images of the patient's internal organs, bones, etc. The use of two different types of physical signals – electromagnetic and acoustic waves – allows for combining the strengths of each method to obtain images of both high resolution and high contrast.

"In the case when the sound propagates at nearly constant speed inside the body – for example, in breast imaging – the image reconstruction problem is mathematically equivalent to the integral-geometric problem of determining an unknown function from its integrals along circles in 2D imaging or spheres in 3D imaging, i.e., the inversion of the so-called circular (in 2D) or spherical (in 3D) Radon transform," he said. "A big portion of my early research was dedicated to the study of these transforms."

Ambartsoumian was born in Yerevan, Armenia – one of the oldest cities in the world, founded in 782 B.C. – and grew up in the nearby town of Metsamor. His father worked as an engineer at the Armenian Nuclear Power Plant and his mother taught high school physics for years.

"So in some way, it was natural that I would choose my future career in engineering or science, although I must confess that for a while I wanted to become a professional soccer player," he said. "In any case, I think that my analytic mindset and love for rigor and coherence ensured my choice of mathematics, and I have never regretted that."

After finishing high school in Armenia, he moved to Russia to study Applied Mathematics at the Obninsk Institute of Nuclear Power Engineering. He was 16 and said it was "quite an experience" living several thousand miles from home, handling school and adjusting to a new environment.

"It took me a couple of semesters to feel completely acclimated, and since then I have been quite comfortable with any sort of transitions across borders and/or cultures," he said. "It may sound like a cliché, but I do feel like a citizen of the world now."

In the final year of his studies in Russia, Ambartsoumian applied to Ph.D. programs in the United States. The first school he heard back from was Texas A&M; University, with an "offer that I could not refuse," he says. After graduating from

Obninsk in 2001, he moved to College Station to pursue a Ph.D. in Mathematics.

When he came to the United States, Ambartsoumian had a basic knowledge of English, good enough for reading and writing, but he found listening comprehension and speaking to be more of a challenge. The universal language of mathematics aided him in his effort to master English.

"The good thing is that in mathematics the lectures are usually filled with formulas, so I could still follow the narrative," he said. "In a semester or so I became completely comfortable with all aspects of the language."

At Texas A&M;, Ambartsoumian asked Peter Kuchment, a Distinguished Professor of Mathematics and a leading researcher in mathematical techniques for medical imaging, to be his Ph.D. advisor. Kuchment agreed and the two developed a close rapport. They went on to publish several well-received papers together detailing their research on thermoacoustic tomography and circular Radon transforms.

"I could see he was very well-prepared and he did very good work," Kuchment said. "He took several courses of mine and he was always the best student in class. Some of the papers we did together became very well-known and they prepared him to be very successful once he left here."

Kuchment said medical imaging research is exciting because it has the potential to revolutionize the way cancer and disease are detected and treated. He also said for researchers, it's important in another way.

"The new generation of medical imaging technology promises much better images and is much cheaper and safer than current imaging technology," Kuchment said. "For a mathematician and researcher, the main thing isn't only that breakthroughs in research could save more lives, but also that you have to enjoy it and have fun doing it. The research being done in this field is very difficult, very beautiful and very challenging, and that's what you need to have as a researcher to have fulfillment – a challenge. It makes all the hard work enjoyable."

After earning his Ph.D. in 2006, Ambartsoumian accepted a job offer from UT Arlington. He says his decision was influenced by the fact that UT Arlington was striving to reach Tier I status; the Math Department had a strong research program and a good Ph.D. program with a long history; and it was close to UT Southwestern Medical School, which he saw as a great opportunity to collaborate with scientists there on research which interested him, including medical imaging and tomography.

He is excited to have the chance to find new ways to utilize mathematical formulas that seem incomprehensible to many in order to improve technology that can be beneficial to all.

"It's a wonderful field to be in because the possibilities are endless," Ambartsoumian said. "We really have only scratched the surface and I'm very much looking forward to finding other ways that we as mathematicians can help improve society."