COS NEWS

Ambartsoumian leading NSF-funded project to develop new math theory for improvement of imaging technology

Researchers at The University of Texas at Arlington are working on a project which addresses a variety of mathematical problems that are significant for various fields of imaging. They believe the results of their study could have a sizable impact on imaging technology used in things such as modern healthcare equipment, national security, space exploration, and industrial applications.

Gaik Ambartsoumian, associate professor of mathematics, is principal investigator of the project, which is titled “Conical Radon transforms and their applications in tomography” and is funded by a three-year, $197,628 grant from the National Science Foundation’s Division of Mathematical Sciences.

Ambartsoumian is joined in the work by co-PI Venkateswaran Krishnan, a faculty member in the Center for Applicable Mathematics at Tata Institute of Fundamental Research in Bangalore, India, and by three doctoral students working in Ambartsoumian’s group: Sl-Ghi Choi, Mohammad Javad Latifi Jebelli, and John Montalbo.

The project also provides research experience to 3-4 undergraduate students, who are exposed to sophisticated mathematics with applications to real-world problems. This year, undergraduate students Srivani Gandikota, Brendon Hotchkiss, and Javier Salazar will participate in the project. Special emphasis is being made on training students from groups historically underrepresented in STEM fields, including women and minorities, Ambartsoumian said.

Tomography is a technique for creating three-dimensional images of the internal structures of a solid object by analyzing the travel of waves of energy, such as X-rays, electromagnetic or acoustic waves, through the object. The production of images generated by tomography is usually based on the mathematical procedure called tomographic reconstruction, which is a kind of multidimensional inverse problem where the goal is to generate an estimate of a specific system from a finite number of projections.

The techniques directly related to Ambartsoumian’s project include single-scattering optical tomography and gamma ray emission tomography, which are used in medicine for diagnostics and treatment monitoring of various diseases; as well as Compton camera imaging, which is used for detection of radiation sources in homeland security and in radio astronomy; and a few others, he said.

“We are working on the development of a new mathematical theory necessary for the advancement of imaging techniques in optical tomography and cameras using Compton scattering effect,” Ambartsoumian said. “More specifically, we are studying the properties and deriving inversion formulas and algorithms for the broken-ray and conical Radon transforms, which are at the forefront of scientific endeavors in modern integral geometry and inverse problems.”

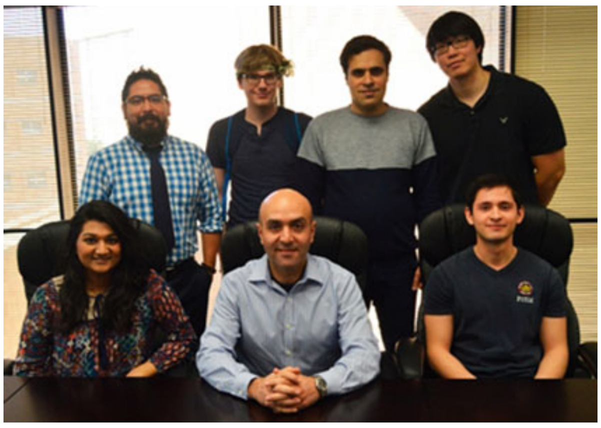
Single-scattering optical tomography is a unique, three-dimensional optical imaging technique. It utilizes angularly selective measurements of scattered light intensity to reconstruct the optical properties of macroscopically inhomogeneous media, assuming that the measured light is predominantly single scattered.

Gamma ray emission tomography is a functional imaging technique which is used to observe metabolic processes in the body. The system detects pairs of gamma rays emitted indirectly by a positron-emitting radionuclide, or tracer, which is introduced into the body on a biologically active molecule. Three-dimensional images of tracer concentration within the body are then constructed by computer analysis.

Compton camera imaging is a technique which uses Compton scattering to determine the origin of the observed gamma rays. Compton scattering is the inelastic scattering of a photon by a charged particle, usually an electron. It results in a decrease in energy (increase in wavelength) of the photon (which may be a gamma ray or an X-ray), called the Compton effect.

The project is devoted to the study of broken ray transforms (BRT) and conical Radon transforms (CRT), and their applications to several modern imaging modalities, Ambartsoumian said. A broken ray transform maps a function defined on a plane to its integrals along a certain family of broken rays. A conical Radon transform maps a function defined in the 3D space to its integrals over a family of conical surfaces.

“These quantities often correspond to measurements of an imaging device, and the process of image reconstruction depends on the possibility of stable inversion of these transforms,” he said.



Seated from left: Srivani Gandikota, Gaik Ambartsoumian and Javier Salazar. Standing, from left:John Montalbo, Brendon Hotchkiss, Mohammad Javad Latifi Jebelli and Sl-Ghi Choi.

The main problems to be addressed by the researchers include: the description of injectivity sets of BRT/CRT and formulas for their inversion; the study of the microlocal properties of these transforms; the description of their range; and the investigation of incomplete data problems. The methodology with which they will address these problems utilizes various combinations of techniques from Fourier analysis, partial differential equations, integral equations and microlocal analysis, Ambartsoumian said.

This is Ambartsoumian’s second NSF-funded project with Krishnan, with whom he has collaborated on numerous projects. In 2011 the pair received a four-year, $176,000 NSF grant for their study, “Elliptical Radon transforms in image reconstruction.”

“Luckily, collaborating on mathematical problems over long distances is much easier than in many other sciences, where experiments are essential,” Ambartsoumian said.

Jianzhong Su, professor and chair of the Department of Mathematics, said the project has the potential to improve the technology used to diagnose and treat cancer and other diseases, which helps further UTA’s commitment to improving health and the human condition, one of four main pillars of the University’s Strategic Plan 2020 Bold Solutions | Global Impact.

“Dr. Ambartsoumian’s project can help to make key improvements in the effectiveness of various methods of tomography,” Su said. “Improving these transforms can lead to greater accuracy of the images obtained from imaging modalities such as computed tomography (known as CT) and ultrasound scanning, and could lead to improved airport security and advances in space exploration.”

Ambartsoumian came to UTA in 2006. He received a degree in Applied Mathematics from Obninsk Institute of Nuclear Power Engineering in Obninsk, Russia, in 2001, and a Ph.D. in Mathematics from Texas A&M University in 2006. In addition to mathematical problems of imaging, his research focuses on computerized tomography, inverse problems, and integral geometry. He received the UTA College of Science Outstanding Faculty Teaching Award for 2012-13.

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