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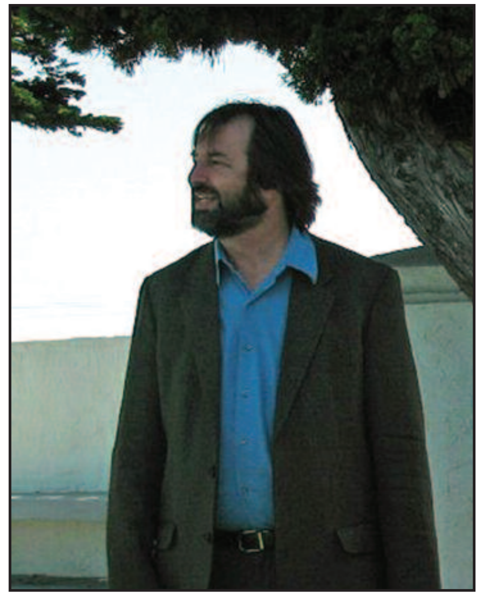
Obituaries: Dennis Healy

Dennis Healy, a professor of mathematics at the University of Maryland and a program manager at the Defense Advanced Research Projects Agency, died on September 3, 2009, after a brief and courageous fight with cancer.

Dennis was born on May 28, 1957, in Santa Monica, California. He received a PhD in 1986 from the University of California, San Diego; he wrote his dissertation, *A Relationship Between Harmonic Analysis on SU(2) and on SL(2,C)/SU(2)*, under the supervision of Audrey Terras. That summer, he and his wife Kathy Hart, an artist, made the cross-country trip to Hanover, New Hampshire. They set up shop in a little house on Occom Pond, a stone's throw from the Dartmouth campus, where Dennis would begin a tenure-track position as an assistant professor in the then Department of Mathematics and Computer Science at Dartmouth College. Dennis would never really lose his surfer-boy demeanor, but by most accounts (including Kathy's) the Hart-Healys adapted quickly to life in a small New England college town.



Dennis Healy, 1957–2009

Dennis's thesis made interesting connections between two of the most well-studied groups in harmonic analysis. Although various threads of the investigation would have implications for his later work, this was decidedly not applied research. On arriving at Dartmouth, however, Dennis began a slow but steady march toward applied mathematics. For anyone who knew him, this was probably not much of a surprise—he had received a BS in physics and a scientific discussion with him would quickly reveal how much hard, empirical science Dennis knew, from the physics of a star to the workings of a CAT scan. Along those lines, one of Dan Rockmore's favorite stories was the time that Dennis almost blew himself up in the UCSD physics lab while trying to repeat some Nobel Prize-winning experiment. He loved technology and lab science.

Rather than taking the usual tenure-track path of producing an obvious pile of papers from his dissertation, Dennis spent the first several years of his career talking to people. He spoke to engineers and medical physicists at Dartmouth, and he became fast friends with another new hire, Jim Driscoll, a computer scientist from Carnegie Mellon. Together, they were part of a department outpost in Choate House, just around the corner from Dennis's home. Dennis could be found there at all hours, amid a sea of papers, books, toys, and posters. At some point someone broke into the office and stole Dennis's computer. When a security officer stopped by to take a statement, he remarked that the thieves had really done a number on the place; Dennis had to admit that no, all they had done was take the machine. The office was just fine.

The "Wavelet Warriors" of Dartmouth College, ca. 1995. Left to right (with current affiliations): Peter Kostelec (Lincoln Lab), Dan Rockmore (Dartmouth College), Doug Warner (Aptina Imaging Corporation), Digger, Charlie, Sumit Chawla (Apple), Tim Olson (University of Florida), Geoff Davis (Google), and Dennis Healy.

Dennis also made regular summer visits to the Naval Surface Warfare Center in San Diego. He went to meetings and listened—really listened. Dennis had a life-long ability to find the nuggets of gold in even the most dross-filled talk at a meeting. As many liked to remark, Dennis at a conference was like a kid in a candy store.

Along with the talking there was of course a lot of work. Dennis immersed himself in the most recent advances in harmonic analysis (i.e., in the time-frequency analysis of wavelets). He simulated everything that he learned: For Dennis, the computer was an extension of his thought processes and his understanding, like his own sixth sense. He cranked all he could out of the early versions of Mathematica on his Mac II, creating animations of wavelet and spherical harmonic expansions that practically made the memory-poor machine catch fire. Eventually, this combination of listening, talking, computing, and thinking would lead to his (and possibly Dartmouth's) first DARPA grant, written with Driscoll and the local eminence grise, Reese Prosser, for research on novel waveform design. This would lead to Dennis's first big (collaborative) hits in medical imaging and noncommutative FFTs.

The group, the "wavelet warriors," had a basic philosophy, largely communicated by Dennis, that, according to Dan Rockmore, still informs the way applied mathematics is practiced at Dartmouth College: Through mathematical insight came scientific and technological progress. It was during this time that Dennis began to work more closely with several Department of Defense agencies, especially DARPA—thus entering the next chapter of his professional life. While "raising" the research group, he and Kathy were also raising a young family, that by then included two sons, Daniel and William, both born in Hanover and the group's youngest wavelet warriors. These were good days.

Dennis was a gifted researcher who had a deep understanding of many subjects and engaged in far-flung collaborations. With his boundless energy and intellectual curiosity, and his obvious delight in exploring new technical frontiers, he was described throughout his career as "a kid in a candy store." Early in his career he recognized the potential of wavelets, and more generally harmonic analysis, to impact numerous applications. When he initially sought funding for his research, he said, only DARPA was investing in the area. One of his first and lasting interests was the development of wavelet theory and its application to magnetic resonance imaging; he worked in this area with John Weaver, a medical physicist at Dartmouth–Hitchcock Medical Center, and Jim Driscoll.

As Weaver recalls, "After we spent time understanding MRI and wavelets, we saw selective RF pulses could be used to excite wavelet profiles instead of single slices. That is the key idea allowing the spin profile to be encoded using a wavelet transform instead of the more natural Fourier transform. Two impediments existed: the signal-to-noise loss and the ordering of the excited profiles. Dennis and Jim found a general method of ordering the excited profiles so the time between excitations is relatively constant for all spins, keeping the image contrast the same for all spins. The loss of signal-to-noise ratio is the real limit of the method." Dennis took the lead in using wavelet encoding to update image information swiftly by exploiting wavelet-based image compression techniques.[1] Wavelets were then in the news, Weaver says, and *Business Week* and several newspapers ran stories on the work. During that time, he and Dennis wrote the first paper on wavelet filtering, anticipating some later work on soft thresholding.[2]

Dennis was also very well known for his groundbreaking work with Jim Driscoll on the development of a fast (exact) spherical harmonic transform, or "FFT on the 2-sphere."[3] The "Driscoll–Healy transform" is akin to the Cooley–Tukey FFT, but for functions on the 2-sphere; it produces an $O(B^2 \log^2 B)$ algorithm for computing the $O(B^2)$ spherical harmonic coefficients for a "band-limited" function of bandwidth B on the 2-sphere.[4] Dennis's work in this area was motivated by real-world problems, including climate modeling, MRI, computer vision, and astrophysics. An enduring legacy of this effort is SpharmonicKit,[5] an open-source software package for computing spherical (and related) transforms. Much current work in noncommutative FFTs for continuous groups can be traced back to that seminal paper.

From 1996 on, Dennis served almost continuously as a program manager at DARPA, first for the Applied and Computational Mathematics Program in the Defense Sciences Office, and subsequently in the Microelectronics Technology Office. For several years during that time, he was also a research consultant to the Advanced Biosensor Program of the National Institute for Alcohol Abuse and Alcoholism of the National Institutes of Health. In 1999, he joined the faculty of the University of Maryland.

At DARPA, Dennis established a diverse portfolio of programs that will continue to have a significant impact on the DoD mission. His programs have been influential in getting the community to think differently about how information is processed. He is most closely associated with Integrated Sensing and Processing (ISP) and Joint Design and Optimization, which have led to compressive sampling and have had a broad impact on measurement theory. Conventional measurement system design assumes that one will first measure (sense) some explicitly defined signal or parameter, such as "the temperature" or "the image," and then process that data. ISP methodology, in contrast, makes no a priori assumptions regarding the staging, the means (e.g., analog vs. digital, hardware vs. software), or the architecture (e.g., interconnection topology) used for sensing and processing. Instead, physics-based models and fast data-adaptive representations allow the co-design of physical measurements and signal processing, with the goal of reducing the number of degrees of freedom in the sensor system's design and operation.

The MONTAGE program expanded the ISP concept to end-to-end integration of optical imaging systems, by considering the trade-off space between traditional optics and modern computing capability. This paradigm results in a radical break with a traditional view of camera design dating back a thousand years. Recent advances in system optimization methods allow the co-design and joint optimization of the optical, detection, and processing aspects of imagers. MONTAGE breaks the Fourier optics paradigm to replace the large, long-lens cameras of today with thin, lightweight cameras that have exceptional performance.

Dennis also created and managed numerous outside-the-box information-processing programs, including STAP Boy, A-to-I, and programs in quantum computation. The vision for the Space-Time Adaptive Processing program (aka STAP Boy) was to harness the power of modern graphics processing chips used in computer games to put teraflop/s signal processing into the hands of the individual soldier. Analog to Information (aka A-to-I, in a play on the phrase A-to-D), challenged the community to find a shorter and more efficient way of going from analog signals encountered in nature to meaningful information without the costly bits of digitization.

Several years ago, Dennis became a research consultant to the NIAAA, where he helped design and develop a "DARPA-like" program on biosensors for alcohol consumption. Plenty of biosensors of various types were available at the time, but there was a dearth of appropriate platforms that could accurately measure and monitor alcohol consumption. Dennis saw this as an opportunity to apply his ISP concept in a community that was unfamiliar with modern developments in sensor technology. Among the novel sensor concepts explored were high-throughput tissue spectrometers and an implantable sensor.

During his years at DARPA, Dennis took his responsibilities at the University of Maryland *very* seriously. He made a genuine impact in the Department of Mathematics, in part as the principal scientist of the department's Norbert Wiener Center. His office contained his wonderful collection of mathematical and scientific books, of which he was proud, as well as several active computers. Students were always gathered in his office when he was there, whether undergraduates, students from his lively graduate Applied Harmonic Analysis course at the Norbert Wiener

[1] D.M. Healy, Jr., and J.B. Weaver, *Two applications of wavelet transforms in MR imaging*, IEEE Trans. Info. Theory: Special Issue on Wavelets, 38:2 (1992), 840–860.

[2] J.B. Weaver, Yansun Xu, D.M. Healy, Jr., and L.D. Cromwell, *Filtering noise from images with wavelet transforms*, Magnetic Resonance in Medicine, 21 (1991), 288–295.

[3] J.R. Driscoll and D.M. Healy, Jr., *Computing Fourier transforms and convolutions on the 2-sphere*, Proc. 34th IEEE FOCS, (1989), 344–349 (extended abstract); Adv. in Appl. Math., 15 (1994), 202–250).

[4] A bandlimited function of bandwidth B on the 2-sphere is one whose harmonics of order greater than B are zero. Note that such a function has at most B^2 harmonics.

[5] http://www.cs.dartmouth.edu/~geelong/sphere/.

Center, or his graduate students.

With all his success, Dennis retained the wonderful qualities that commanded admiration, respect, and affection among his many friends, colleagues, students, and investigators; all who knew him considered him an exceptional human being—modest, kind, positive, charming, and witty. Above all, Dennis was devoted to Kathy and their sons Daniel and William.

We have lost a dear friend and colleague and shall miss him.—*John Benedetto, University of Maryland; Karen Peterson, National Institute of Biomedical Imaging and Bioengineering; Dan Rockmore, Dartmouth College; Anna Tsao, AlgoTek, Inc.; and Steven Wax, DARPA/DSO.*

With special thanks to Ravi Athale, Mitre Corporation; David Brady, Duke University; Sumit Chawla, Apple; Geoffrey Davis, Google; Jim Driscoll; Michael Eckardt, University of Maine; Leslie Greengard, Courant Institute; Kathy Hart Healy; Peter Kostelec, Lincoln Lab; Greg Kovacs, DARPA/MTO; Jian Lu, Vobile, Inc.; Sean Moore, Avaya, Inc.; Arje Nachman, Air Force Office of Scientific Research; Sean O'Connor, Indiana University; Tim Olson, University of Florida; Carey Priebe, Johns Hopkins University; and John Weaver, Dartmouth–Hitchcock Medical Center.

Many of Dennis's friends and colleagues have sent additional reminiscences, stories, and comments.

One of my strongest memories of Dennis comes from one quintessential New England winter's night. He and I had been in the office, working into the wee hours of the morning, finishing up some piece of work—either a proposal or a paper. It snowed heavily almost all night long, but by the time we had finished, the snowstorm had also come to an end. We turned out the lights and walked outside into a still and snow-covered campus. We decided to take a night-time stroll past the Green (now white!) and down Main Street to clear our heads before walking home. After the night of hard work, we were in high spirits, and clowned around, throwing snowballs, shaking snow off tree branches, and just generally goofing around in the local winter wonderland. At some point we stopped and stared up into the kind of beautiful, clear, and starry night that can be found only far from a city. I could hardly tell the difference between the North Star and the Dog Star, but Dennis gave me one of his excited and expert tours of the night sky. It was a night that I think stands for Dennis's career at Dartmouth—-having fun, doing math, and delighting in the simple and sometimes hidden beauties of Nature and small-town New England."—*Dan Rockmore.*

Dennis was an exceptionally effective program manager, even by DARPA standards. His 13-year tour was divided between two DARPA offices, and truly both are better for having had him there. His passion for the impact that mathematical thinking and insights could bring to applications, combined with remarkable brilliance, creativity, and vision, enabled him to create research agendas that will have an enduring impact on computers, imaging, health care, and information processing for our national defense and country.

As DARPA programs get absorbed into the mainstream, they are often forgotten, but none of us will ever forget Dennis, our colleague, our friend. Those of us who were at DARPA when Dennis showed up on our doorstep knew instantly that he was someone special. It wasn't just his intelligence, which was remarkable. It wasn't just his passion for using mathematics to make a difference to the nation's defense, which he did in spades. And it wasn't just his near photographic memory, which often left us in awe. It was that he never gave the impression that he was in any way more intelligent or more passionate than the rest of us, even though he was! In an agency known for huge egos, an ego was about the only thing Dennis didn't bring to his time at DARPA.

Despite working essentially two jobs (and sometimes three), Dennis was always willing to help and teach others. A special gift was his ability to describe what he was doing in a way that allowed those of us who are math challenged (which most of us are) to grasp the concepts and see the beauty of the mathematical approaches he was taking.

Each of us has different specific memories of time spent with Dennis. Some of us remember naming rock tunes and artists, discussing sports, even taking part in a few heated debates about the Constitution. Dennis's charm was that he was equally at home with almost every imaginable subject. Sadly, some of us watched Dennis, Kathy, and their boys valiantly deal with his last ordeal. Through it all, we remember one of the most special people any of us will ever meet. We are to a person better for having known him.—*Dennis's DARPA friends*.

I met Dennis Healy right after he joined Anna Tsao at DARPA to help manage the mathematics program there. Given that his own area of expertise was more aligned with wavelets, I was astonished at how quickly he "metabolized" the details of the substantial computational electromagnetics program that was then part of the DARPA math portfolio. After that I came to expect such mental agility and looked forward to being included in some of his projects, both acting as an agent for his DARPA funding and reviewing (or finding reviewers for) some of the fascinating proposals that came his way as a result of his considerable gift for conceiving new directions. I was also seriously impressed by his gifts as a PowerPoint slidemeister—program managers at DARPA can act on their ideas only if they are able to "sell" them to management.

My last project as an agent for Dennis involved an attempt to produce cyclic ozone using laser beams as optical tweezers. Dennis not only understood the physics of this effort but also identified a compelling part that mathematics could play. I will miss Dennis. He was my friend and teacher.—*Arje Nachman.*

Dennis's vision for measurement and signal exploitation was compelling and infectious. His laptop struggled mightily to contain his many examples and projects in optics, radar, MRI, x-ray, and quantum physics. I recall several meetings at which he would have 10–20 presentations simultaneously open, each demonstrating the integrated sensing and processing methodology from a different direction.

Eventually, Dennis Healy's vision will influence all measurement systems, including cameras, radar, MRI, CT, and point transducers like thermometers and strain gages. For the past 50 years, concepts of measurement have been dominated by direct application of Shannon sampling theory, which is actually effective only after physical/digital transduction. Dennis's approach emphasizes the impact of physical/digital transduction in creating information and exploits resulting opportunities to dramatically improve efficiency. The impact of his approach is already clear in the outcome of the Advanced Biosensors program. In our case, static mask coded aperture technologies developed with Dennis's help have been transferred to diverse applications.—*David Brady.*

Interacting with Dennis was both a pleasure and a privilege. It was a pleasure because I enjoyed watching his mind work, and working with him to move the biosensors program forward. It was a privilege, because he worked on so many projects with so many people. This meant that he was not always a rapid or regular correspondent; phone calls may have been unreturned for some time, and e-mails might have been ignored—not due to a lack of interest or involvement, but rather due to his own version of networking. He was like the server in a vast human computer network, giving attention in turn to each of us in his network. No matter how much time elapsed between our conversations, they resumed exactly where they had left off. He possessed an extraordinary ability to multiplex many complex issues and processes simultaneously and seamlessly.

Dennis was a great builder—of ideas, of programs, and of teams of people. He could find alternative solutions to daunting problems, which is invaluable especially when investigators are being asked to push the envelope of their accomplishments and leave their comfort zones. We struggle to find adequate descriptors for exceptional people. I cannot do justice here to all that Dennis was. He has left behind many monuments to his intelligence and vision, and I am proud to have had the opportunity to work with him on one of those.—*Karen Peterson*.

I was convinced that NIH should develop nanosensors that could be swallowed, but told Dennis that I did not know how to power them other than with batteries, which was not desirable. Dennis looked up at the lights in the ceiling and said “ferromagnetic fields” and then added that friction from people’s shoes could also be used as a source to power nanosensors. For the first time, I knew that Dennis lived in a world that was very different from mine!—*Michael Eckardt.*

Dennis was a friend to me, not so much in a personal role but as a governmental counterpart to my inventive streak. I could focus on the details; Dennis saw the big picture. I could get discouraged; Dennis did not. I could be anxious about missing something; Dennis was there to backstop me and to point out the more productive path. He was kind, prescient, present, and broad-minded. I will miss him.—*Sean O’Connor*.

In the mid-1990s, Dennis sought the counsel of many friends about whether he should accept a position at DARPA. In my infinite wisdom, I assured him that accepting such a position would be a major error, as it would adversely affect his research career. So much for my wisdom. Dennis began at DARPA in 1996.

Once he had moved to the DC area, it seemed to me that we had a remarkable opportunity to hire him at the University of Maryland, College Park; in fact, he was hired as a full professor in 1999. Despite a shift then under way in harmonic analysis, toward what we now call applied or computational harmonic analysis, most of our faculty, to their credit, endorsed hiring in this area. I had known Dennis since about 1990, and had studied the work on non-uniform sampling in his thesis, as well as the work on MRI he did at Dartmouth. Dennis seemed to be an ideal fit for our department at Maryland. In fact, while at Dartmouth, he had hired two of my students as postdocs in the early 1990s.

Very early on, I understood that he was an extraordinarily kind person. He was also a polymath, in a broad area integrating mathematics, statistics, image processing, signal analysis, electromagnetics, and, later, dimension reduction and quantization. We knew that he had many other scientific interests as well. I didn’t understand or know much about his scientific vision until his arrival in Maryland. When we discussed science, I always felt that I was seeing into the future because of him, and it was clear to me, even when he was confronting the most applied topics, that mathematics was the driving force and the guiding light.

Besides the vision that has influenced governmental scientific research, Dennis was actively involved in his own research. Four days before he died, he spoke to me for an hour and a half about his research projects. He was weak, but focused and passionate.—*John Benedetto.*

A shorter version of this obituary appeared in the November 2009 print issue of SIAM News*.*