The quantifier: Building software that interprets medical images

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Polina Golland's parents tell the story that, sometime in the early 1980s, when Polina was in junior high, she announced that she wanted to go to MIT. That's an unusual plan for any 13- or 14-year-old to hatch independently, but particularly one living in the Soviet Union during the Cold War.

Golland, now a newly tenured associate professor in the Department of Electrical Engineering and Computer Science and a principal investigator at the Computer Science and Artificial Intelligence Laboratory (CSAIL), grew up in Frunze (since renamed Bishkek), the capital of Kyrgyzstan, a city of about a million people. "It was actually European in nature," Golland says. "It was mainly Russians." Golland had what she calls a "happy childhood," dominated by physics and math. Both of her parents were physics researchers — her father at a Kyrgyz university and her mother in the National Academy of Sciences — and she was enrolled at the Frunze science school.

Golland doesn't recall the incident, but according to her parents, her ambition to attend MIT awoke when she pulled a volume of the celebrated Lectures on Physics by Richard Feynman '39 off her father's bookshelf. In a stroke of luck, the volume was one that, as the jacket copy declared, Feynman had written while on sabbatical at MIT. If Golland had happened to grab a different volume — who knows, she might have ended up at Caltech.

As an undergrad, however, she initially enrolled at a university in

Moscow, where she got her first taste of the Soviet police state. "Some of my friends in college were called to the KGB and asked to report on what was going on in their discussions," Golland says. "I didn't particularly like that." When, in 1990 — after the fall of the Berlin Wall but before the dissolution of the U.S.S.R. — her parents floated the idea of emigrating to Israel, Golland and her sister were all for it, even though it meant renouncing their Russian citizenship.

After earning both bachelor's and master's degrees in computer science at Israel's Technion Institute of Technology, Golland finally came to MIT for her doctorate — not in fulfillment of a childhood prophesy but simply, she says, "because that's the best school to do a PhD at."

Now a citizen of both the United States and Israel, Golland has been back to Russia only once since 1990. "I feel a lot of connection to Russian culture," she says. "I speak Russian to my 2-year-old, but I don't feel a connection to the country. I sort of view myself as Israeli-American."

Golland describes her educational background as "computer science with an unhealthy dose of math"; during her final semester at the Technion, she took a course whose mathematical rigor appealed to her so much that she decided to do her master's research with the instructor. The course happened to be on image processing, and for her thesis, she developed techniques for extracting information about the motion of objects in digital video — a problem squarely in the mainstream of computer-vision research.

For her PhD work, she had anticipated doing something similar. But when she arrived at MIT, she found that some of her new colleagues were working on algorithms for processing medical-imaging data, and she was intrigued. "Most of my students haven't seen a biomedical image in college," she says. "I get them interested in this area, oftentimes after they are admitted. And the same thing happened to me." For her dissertation, Golland worked on algorithms for identifying variations in the shape of the hippocampus that were correlated with neurological disease.

As a professor, Golland remains interested in anatomical variation, but in a broader range of contexts. How can an algorithm learn to automatically identify organs in medical images, given that the images used to train the algorithm will depict organs with subtly different shapes? Can a mathematical model of organ shape be made flexible enough to identify organs that have been grossly distorted — say, by the pressure of a tumor? How do organs change shape as a disease progresses?

She's also branched out to another major area of research: modeling brain activity. Functional magnetic resonance imaging (fMRI), which can measure oxygen levels in animal tissue, has been used to identify regions of the brain that receive a rush of blood when test subjects are asked to perform certain cognitive tasks. But many complex tasks, rather than sparking a lot of activity in one region, spark subtle activity in a lot of different regions, which can be very difficult to distinguish from the background hum of the resting brain.

In such cases, simply turning a computer loose on raw fMRI data and asking it to look for patterns would be fruitless. So Golland's group is working closely with a number of neuroscientists, who provide working hypotheses about brain activity that serve as the basis for mathematical models. These models tend to bring the hypotheses into sharper focus, which leads to their revision, which leads to new models, and so on, in a continual process of iteration. "I love that process," Golland says. "They refine their notions of what they're trying to formulate, and we understand much more about what's known about the biology.

And that points to one of the reasons that analyzing medical images appealed to Golland so much in the first place. “It’s lots of fun, because I get to stay a student all the time,” she says. “By the nature of it, we always have to keep learning about it.”

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