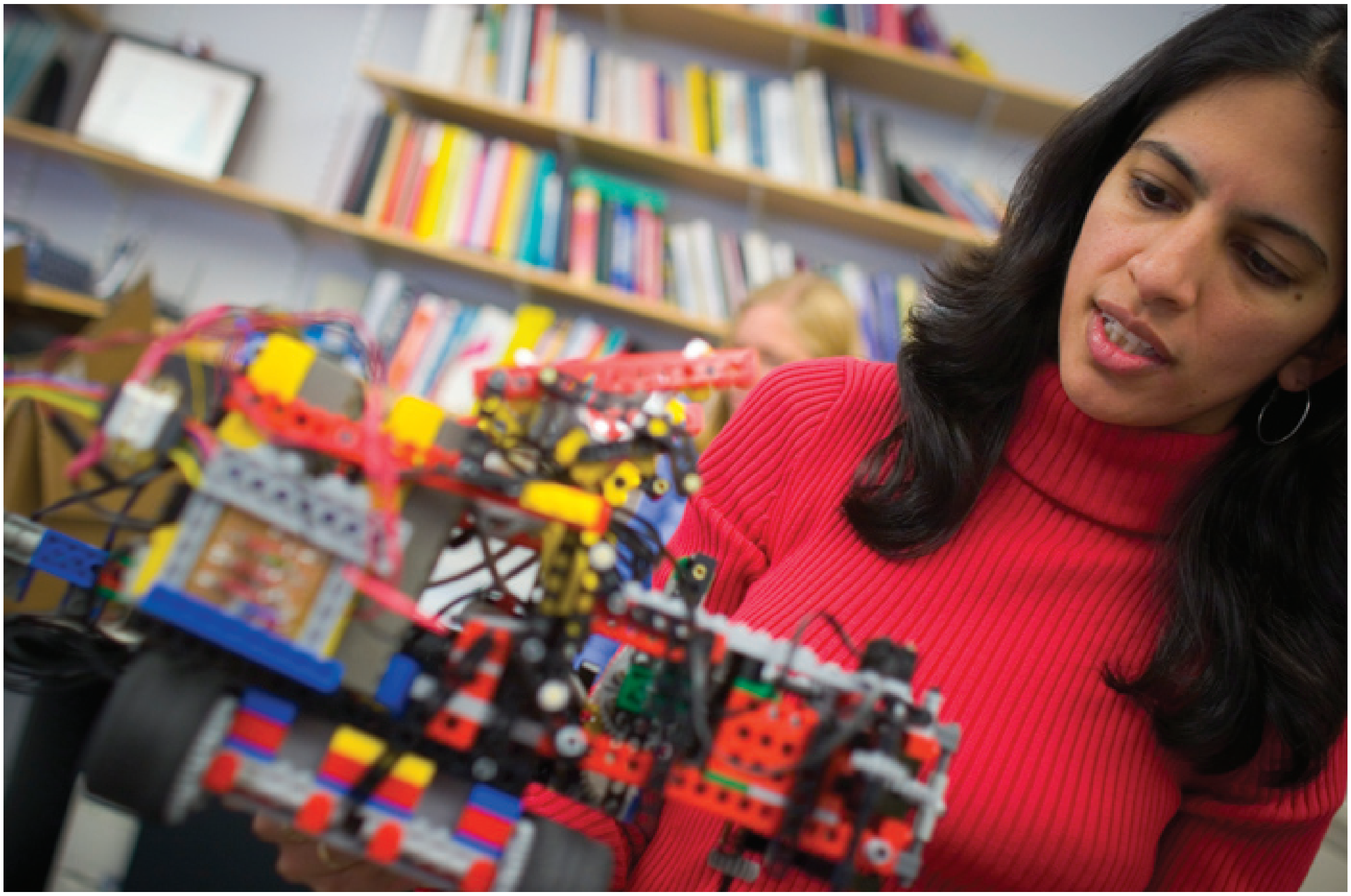

Balancing risk with reward, computer scientist Radhika Nagpal has found success. (Justin Ide/Harvard News Office, © 2006 President and Fellows of Harvard College.)

Radhika Nagpal

Adapting to Risk

The black lettering on the bright yellow tape strung on Radhika Nagpal's office door reads: "ABSTRACTION BARRIER—DO NOT CROSS". With the door slightly ajar, the petite computer scientist looks quite real and friendly, sitting upright on a small blue couch that matches the color of her jeans. While even the most risk-adverse would realize it is safe to cross the threshold, the like-minded souls who get the joke are particularly welcome. (For the rest of us, it's a core concept from CS 51.)

"I made these buttons with the Harvard seal and 'Nerd Pride' on them," says Nagpal as she spreads out her stash like Halloween candy. She gives the buttons to her students, explaining that it was originally an "MIT thing"—referencing the institution where she pursued her undergraduate and graduate degrees in computer science. "Happily, people are just as nerdy here as they are at MIT," she says. The image of computer science as a haven for nerds drives away some people, especially women, but Nagpal has dedicated herself to reprogramming the word. As a confident, self-proclaimed nerd herself, she's a compelling counterexample to the stereotype.

"When I think of 'nerdy,' I think of people who can get so excited about the intellectual part of research separate from what meaning it has for society," she explains. For Nagpal, being "nerdy" means having the courage to take huge risks. She cites the famed essay "Technology and Courage" by Sun Microsystems' Ivan Sutherland in support. Nagpal uses the "Nerd Pride" message as a small way to celebrate and encourage intellectual daredevils, a phrase that also suits her.

Uncharted waters

"I like to work in areas people haven't thought about for a long time or bring an idea to the table that is by its very nature, different," she explains. Nagpal, who first spent a year at the newly formed Systems Biology Department at the Medical School before settling in as an Assistant Professor of Computer Science at HSEAS, has been doubly rewarded for exploring uncharted areas. She was selected as a 2005 Microsoft Fellow and won a prestigious NSF CAREER Award (see page 11) in 2007; both grants are designed specifically to support rising stars in academia.

Currently, she investigates ways to engineer self-organizing, self-repairing distributing computing systems. Such techniques could be used in everything from fault-tolerant and efficient wireless networks to "smart" houses that efficiently regulate energy consumption. For inspiration, Nagpal looks to nature: multi-cellular organisms and social insect colonies. She wants to find ways to capture, analyze, and convert principles, such as how cells coordinate to form organisms, into algorithms. "The goal is to take inspiration from biology to build new things like reconfigurable robots that can adapt to their environment," she explains.

"The exploration of stuff that is abstract is where you first look when you have something practical in mind."

To illustrate, she shows a video of a self-balancing table one of her graduate students, Chih-Han Yu, built. Fitted with four spindly, multi-jointed robotic "legs," the table can balance a glass of water like a contortion artist walking a tightrope on a windy day. Each "leg" is actually composed of several identical modules; each module coordinates with its neighbors and reacts to local sensing feedback. Although the modules use simple rules, the overall effect seems more complex, as the intelligent table can adapt to changes in motion and surfaces without spilling a drop, even plopping itself down on a couch.

"Originally I had no idea if we'd come up with anything that could be generalized," Nagpal says. "The exercise began with the idea of creating a self-balancing chain" and then evolved into the table concept as a graduate student seized on an untested opportunity. More broadly, Nagpal envisions creating multi-agent systems that always converge toward the right answer and constantly adapt to reduce error. "You do not have to worry about every possible fault or need to write a 'what happens if' scenario with a self-maintaining and self-repairing algorithm," Nagpal says.

Understanding how self-maintenance emerges in artificial systems like the table has, in turn, led her to reconsider biological systems. Together with graduate student Ankit Patel and collaborators at the Harvard Medical School, she has explored how single cell behavior can lead to system-level robustness in epithelia (skin cells) in a *Nature* paper published last summer. Just as one can model simple rules for the table's "legs," one can model rules that describe interactions between a cell and its neighbor.

While the engineered rules led to a level table, Nagpal and Patel discovered that the cell divisions rules lead the tissue towards a fitted cell shape distribution. They were able to predict, with surprising accuracy, how an epithelial tissue would maintain a specific distribution of polygonal cell shapes, across diverse organisms. The question that remains open is whether this collective shape regulation plays a role in tissue development or disease; but for Nagpal, converging toward an answer may be just as important as pinning down the "right" answer.

Collective courage

As with much of her work, Nagpal claims "the exploration of stuff that is abstract is where you first look when you have something practical in mind." She admits that diving in blind—"not knowing what an approach can be used for or what problem it can solve"—isn't easy, not for students concerned about finishing their thesis and launching their careers nor for faculty, like her, working toward tenure and competing for results-based grants.

To make risk-taking safer and more appealing for future computer scientists, Nagpal suggests, as with a robust system, seeking out additional support. "Senior faculty can become ideal advisers," she says. She cautions that it is also critical, especially for students, to find peers who can offer useful criticism and direction; even daredevils need a reality check now and again and a reminder that it is alright to take things slowly. "The skill to think of a problem systematically and take an incremental approach to a subject is essential. If they can grasp that, no matter how long they have on a project, they can make tangible progress," she points out. Moreover, taking encouragement from small victories enables faculty and students alike to gain the confidence to take bigger risks.

The true value of nerd power is finding the strength to combat the uneasy feeling of not knowing what is at the end of the tunnel, or in Nagpal's case, beyond the abstraction barrier. "We often don't know where we are going," says Nagpal. "We need to have the courage to just see how far we can think." ☼

The "balancing table" built in Nagpal's lab, an example of a multi-agent system that converges towards the right answer (or in this case, staying upright). "The table idea is actually just one possible way to think about this concept," explains Nagpal. "Another is a bridge, or a programmable assembly surface on which you could move objects. Just think of a surface made up of several of these 'table-like' panels connected in an array. In that way our original idea for a self-balancing chain has evolved not into just a table, but into a more general 'self-adaptive structures' concept."