



# chasing rabbits.

The winding career path of **Tuomas Sandholm** has taken detours through kidney transplants, Texas Hold 'em, windsurfing and more. Next, he'd like to save the planet.

by Sean D. Hamill

photos by  
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Thomas Sandholm remembers the year the cod disappeared from Helsinki.

He was about 10 years old and spent much of his free time on or in the waters around Helsinki, Finland, learning to sail and fish. Typically, when the cod were running, Sandholm remembers barely putting his bait in the water before he got a bite. But that particular summer, there were no cod. They seemed to have vanished inexplicably.

“I felt that very, very personally,” Sandholm says.

In the late 1970s, as a kid, he had no idea what he could do to solve the problem — which may have been due to pollution.

Now, Sandholm is 48 and one of the world’s leading authorities on artificial intelligence as a computer science professor at Carnegie Mellon University. That sense of loss when the cod disappeared has him looking for his next major project.

“I’d like to do something for the planet,” Sandholm says

during an interview in his not-quite-cluttered-not-quite-neat office, which overlooks a small green space next to the busy series of buildings that make up CMU’s Gates-Hillman complex.

For many, helping the planet is a vague and half-hearted goal. Sandholm, though, has the experience — and the tenacity — to achieve whatever goals he sets.

His accomplishments in artificial intelligence have benefited business, security industries and even kidney transplantation. His work has centered around the



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development of algorithms that can sort through data in search of solutions to pressing problems.

Last year, he ranked as the ninth most influential artificial-intelligence scholar in the world, according to research site AMiner (which uses algorithms of its own to track citations of scholars’ work in significant publications). Now, though, Sandholm is searching for a new challenge — the next problem worthy of his considerable talents.

Whatever he decides to pursue, his wife of 17 years, Christina Fong, a CMU senior research scientist in the Dietrich College of Humanities and Social Sciences, says it won’t be a probing half-effort.

“Once he decides, it’s not much of a thought process for him” afterwards, she says. “It’s more like a dog running after a rabbit. He sees the rabbit and he has to chase it.”

And unlike most dogs, Sandholm almost always catches the rabbit.

That’s not to say he does not fail. In fact, he says, like so many inventors before him, he accepts and relishes failure as a way to learn — a trait he got from his parents.

“I had a very free childhood. There were very little constraints — total ability to fail,” he says.

He grew up on a small island called Tammissalo on the east side of Helsinki, located on the Gulf of Finland but connected by bridges to the mainland. His late father, Markus, was a pharmacologist and toxicologist at the University of Helsinki; he died in 1999 at age 56 from a cancer he contracted researching chemicals, not yet known to be carcinogenic, early in his career. Sandholm's mother, Leena, was a dentist specializing in periodontology and researcher who also ran a dental clinic.

Asked via email about her son, Leena Sandholm offered this illuminating tidbit about him at age 7: "He was climbing up a high, sandy river bank, which I considered dangerous and gave warnings. Tuomas answered: 'Don't destroy my self-confidence.'"

Fong says the stories she has been told by Sandholm's family over the past two decades — they started dating seven years before their marriage — paint a picture of a precocious, energetic child who might not have fared as well in another setting (or with more confining parents).

"When he was a kid, he would get outside and just be gone," she says. "It just sounds like they were barely able to contain him. If he'd been in the U.S. — this really bright and energetic kid — it might have led down the wrong path. But he was in a forgiving environment."

He loved building with LEGO bricks as a kid — not from the planned, mapped-out superhero or action sets found in toy stores today, but from the unstructured boxes of random pieces that once served as the go-to toy for industrious youngsters. He was doing well in school; at 13, his mother asked Sandholm and his brother if they wanted to try a week-long computer class. The Finnish-language course used a computer with only three kilobytes of memory; nevertheless, Sandholm's interest was piqued. A year later, his school — where lessons were taught in English by Catholic sisters — added some pre-Macintosh Apple computers.

"I just liked it right away," he says. "I don't really know what it was. But it was just so easy to make something."

Students were told they could play with the computers as much as they wanted outside of the class. Often, though, it ended up with just Sandholm by himself in the computer lab (with a sister assigned to keep watch).

He began building programs almost immediately, including a self-teaching language-learning program. Another time, his mother recalls, "He participated in a competition of making computer games. His program was considered too large and complicated to be accepted."

After his obligatory year serving in the Finnish armed forces — he rose to second lieutenant as a pilot in the Air Force Academy — Sandholm went to college at the Helsinki University of Technology. Though he started out as an industrial engineering and management science major, he began to focus on computer science and game theory, a branch of applied mathematics.

In 1989, at age 20, he began searching for a topic for his master's thesis (the university program he was enrolled in was similar to a combined bachelor's and master's program). A pair of trucking companies had approached the technology program looking for help

making itself more efficient after it noticed it had too many trucks driving around empty after dropping off deliveries.

Sandholm's approach was to attack the problem as one of "optimization," a theme he would come back to again and again in his career. He devised a program that allowed the trucking company to save money by finding the optimal route and pick-up schedule among its customers. Such a program now may seem typical, but then it was groundbreaking; Sandholm was teaching software, which is programmed towards self-interest, to negotiate with other software on its own.

Sandholm also spent some time working on a theoretical idea that was so far ahead of its time, some of his colleagues dismissed it as fantasy: An online marketplace where people would buy things using interconnected computers, even though they could not touch or see those things in person.

"I felt very fortunate the web came through. If the web had not come through, people would have thought I was crazy," he says with a hearty laugh. "So [the creation of the web] was validation, and I'm grateful for that."

He then put his focus on getting into the University of Massachusetts Amherst, where Victor Lesser, a pioneer in AI research and what are known as multiagent systems, worked with a team of expert colleagues.

UMass would prove to be doubly beneficial for Sandholm, who met Fong, then a doctoral student at the school, during a midsummer party a friend organized for all of her Finnish friends (including Sandholm) and her horse-riding friends (including Fong).

For the couple's first date, they were going to go water skiing, but it rained. Instead they had dinner and played the board game Othello. Fong beat him 11 straight times. She had played the game on a computer before but didn't tell him that until the end. When she did tell him, Sandholm laughed, impressed.

"He was so happy to be taken down by a successful bluff," she says.

They became inseparable after that, Fong says. They're raising two daughters — Sophia, 11, and Annika, 9 — in their home not far from CMU's campus.

In 1996, Sandholm earned his Ph.D. in computer science. At the time, Lesser — Sandholm's mentor through those years — was upset that the big players in the academic AI world didn't offer Sandholm a position. "I always felt the field was [at the time] too young to understand Tuomas' work," Lesser says.

Titans of the emerging field such as CMU, MIT and Stanford failed to take notice. For the next four years, Sandholm ended up at Washington University in St. Louis. It wasn't the most highly ranked computer science school, but it offered Sandholm something vital: the freedom to research what he wanted. It was there that he started his first company, CombineNet, which used his combinatorial market algorithm to help companies buy products more efficiently.

"What Tuomas comes up with, it's so far ahead of its time," says Tom Finn, who worked with Sandholm at CombineNet to sell his algorithm to companies. "Our market was limited when we started because we couldn't find enough people who understood what was



possible."

CombineNet would eventually grow to 130 employees; in 2010, Sandholm and his investors sold the company.

After moving to CMU in 2001 — finally getting the position his mentor always thought he deserved — Sandholm rocketed into AI superstardom as his concepts began to be more clearly understood. His work was cited more than any other AI research in papers published from 2000-2010, according to Microsoft's Academic website. He became famous not only for the ideas behind his work, but also how that work touched on so many different topics.

"The breadth of the work he does is unique," says Kevin Leyton-Brown, professor of computer science at the University of British Columbia in Vancouver, Canada, and a leader in AI research. "It spans an area from computer science to micro-economic theory. And he's one of a small group of people whose work is more applied and who really builds things."

One algorithm Sandholm created matches living kidney donors from around the United States with people who need a transplant, wading through a sea of data to find optimal matches — thus helping thousands of people get life-saving transplants.

The work he did writing programs that

allow companies to buy goods and services more efficiently has helped save some of the globe's biggest companies billions of dollars and helped make products cheaper for consumers. Other work has helped make advertising more efficient.

The result of all of this, Lesser says proudly of his protégé: "When you talk about the superstars in the field, he's one of them."

Earlier this year, an algorithm Sandholm created with Noam Brown, a Ph.D. student at CMU, won a poker contest. They named it Libratus; it beat some of the world's best human players at no-limit Texas Hold 'em in a competition at Rivers Casino.

Though Brown and Sandholm concede designing poker-playing bots is fun, it was always with the aim of loftier goals. The algorithmic concept behind it — solving what AI folks call "incomplete-information games" where you only know some of what your opponent has or wants — is expected to benefit business, security and even medical situations.

Incomplete information games involve many, many more possible outcomes than, say, chess. In poker, one player never knows exactly what the other players are holding or which cards are already on the table, let alone if anyone is bluffing. Compare that to chess, where a computer can see every piece being played at all times. The added difficulty of teaching a program to master Texas Hold 'em led the AI community to deluge Sandholm with plaudits after his victory.

What binds the three major research areas of Sandholm's career to date — business applications, the kidney exchange and poker — is the task of searching through a massive number of possible solutions in order to find an optimal (or near-optimal) one.

"It's about deeply understanding the problem and knowing what details are not really important," says Lesser, who believes Sandholm could eventually win a Turing Award, the highest honor in computer science, for his work. "From a tech perspective, he's been a real genius on this."

As Sandholm's reputation grew and the success of his efforts began paying off, he found himself drifting back to that summer

nearly 40 years ago when the cod disappeared from Helsinki. Surely, after tackling kidney allocation, helping some of the world's biggest businesses become more efficient and solving what was not long ago thought to be an unsolvable poker game, he could help the environment.

"There are a lot of intellectually interesting topics to do research on. And only a tiny fraction of those will ever make the world a better place," Sandholm says. "But at the intersection of what is interesting and what is going to make the world a better place if it succeeds, there are unlimited research topics."

**A**nd once he does find the planet-saving topic to focus on? Fong says her husband's singular focus becomes almost hard to comprehend as he strings 16- to 18-hour days together.

"He just gets this idea, and he just does it," she says.

Brown, the Ph.D. student who worked with Sandholm on Libratus, has seen that up close and says there is a particular part of Sandholm's character that might get missed: "He's a competitive guy and I think that's good for this field. I'm kind of the same way myself. And being competitive is primary to being successful in general, I think."

Competition. That word comes up about Sandholm quite often. He says it helps steer his focus.

"I like the type of performance-oriented computer science," he says. "I don't really separate it from academics. I think most of academics should be like that. In many fields, it is like that. But other fields steer away from that on purpose. But I'm not like that. So we go for the messiest, toughest, first — instead of looking at the simple abstraction."

For example, when he began his work on the kidney algorithm, there were other teams trying to come up with a similar program. But Sandholm thought he could do it better. And when he began working on poker, he knew there were annual international competitions where teams run their poker programs against each other and declare a winner at the end.

"There is this idea of working on the same problem as others. Because that really accelerates the progress," Sandholm says. "Especially like with the poker and kidney exchanges, where people have the same exact problem to work on and then they really work on it in different research groups around the world. That really accelerates the process."

The downside to competition is that you lose from time to time. But Fong says her husband "is very good at losing."

"Tuomas does love to win," she says. "But he also likes the process. And I'm not sure which is more important to him."

Before the Libratus program beat the best humans at

poker earlier this year, Sandholm's prior program, called Claudico, failed to beat a team of humans in 2015.

"He thought of it much more positively" than just a loss, Fong says. "He was more wrapped up in what he could learn from it."

Sandholm's dedication to this process — interest, effort, failure, learn, repeat — is not confined to programming. A decade ago, he decided he wanted to learn how to do the forward loop in windsurfing.

Yes, in between everything else, Sandholm is a championship windsurfer.

In a forward loop, the windsurfer moves the board up off a wave, then does a full, forward flip while still on the board — and lands standing up. It's an incredibly difficult maneuver if you live near a beach and can practice it every day on wavy surf; a monumentally more difficult one if you're landlocked most of the time in Pittsburgh.

Sandholm was once one of the world's best windsurfers; he finished 1st in Finland's national championship in 1987, 5th that same year in the European championships, and 12th in the world championships. He probably would have gone to the 1988 Olympics with Finland's windsurfing team, but the team's leadership decided not to compete that year.

Yet even after he left behind competitive windsurfing, he still had the fervor to get better at the sport. So two decades later, after he decided that the forward loop was a trick he wanted to learn, he hired former world windsurfing champion Matt Pritchard to train him on his family's annual, two-week trips to Maui.

"He was a little green when we started," Pritchard says. "But now, he's totally got his skills together."

Not only did the pair work together in Maui, but Pritchard also had Sandholm do "dry land" training back home in a swimming pool — visualizing moving his body while diving off a board and using the boom of the windsurfing board in the pool. Fong would videotape some of the sessions and email the video to Pritchard who would reply with comments and recommendations.

"He's so focused and motivated," Pritchard says.

On June 3, 2013 — five years after he began pursuit of this trick — Sandholm finally completed a full loop and was able to land and surf away standing up. Completing the loop "was a single-minded focus" says Fong, who remembers breaking out the Champagne that night in celebration.

"It was extremely similar to his approach to winning the Libratus [poker] competition," she says. "Some people told him he wouldn't be able to do either. But he likes competition. He was not going to stop until he did it."

And that trait just might benefit the planet some day. 🌱

For a video of Sandholm's windsurfing forward loop, go to [pittsburghmagazine.com/sandholm](http://pittsburghmagazine.com/sandholm)

