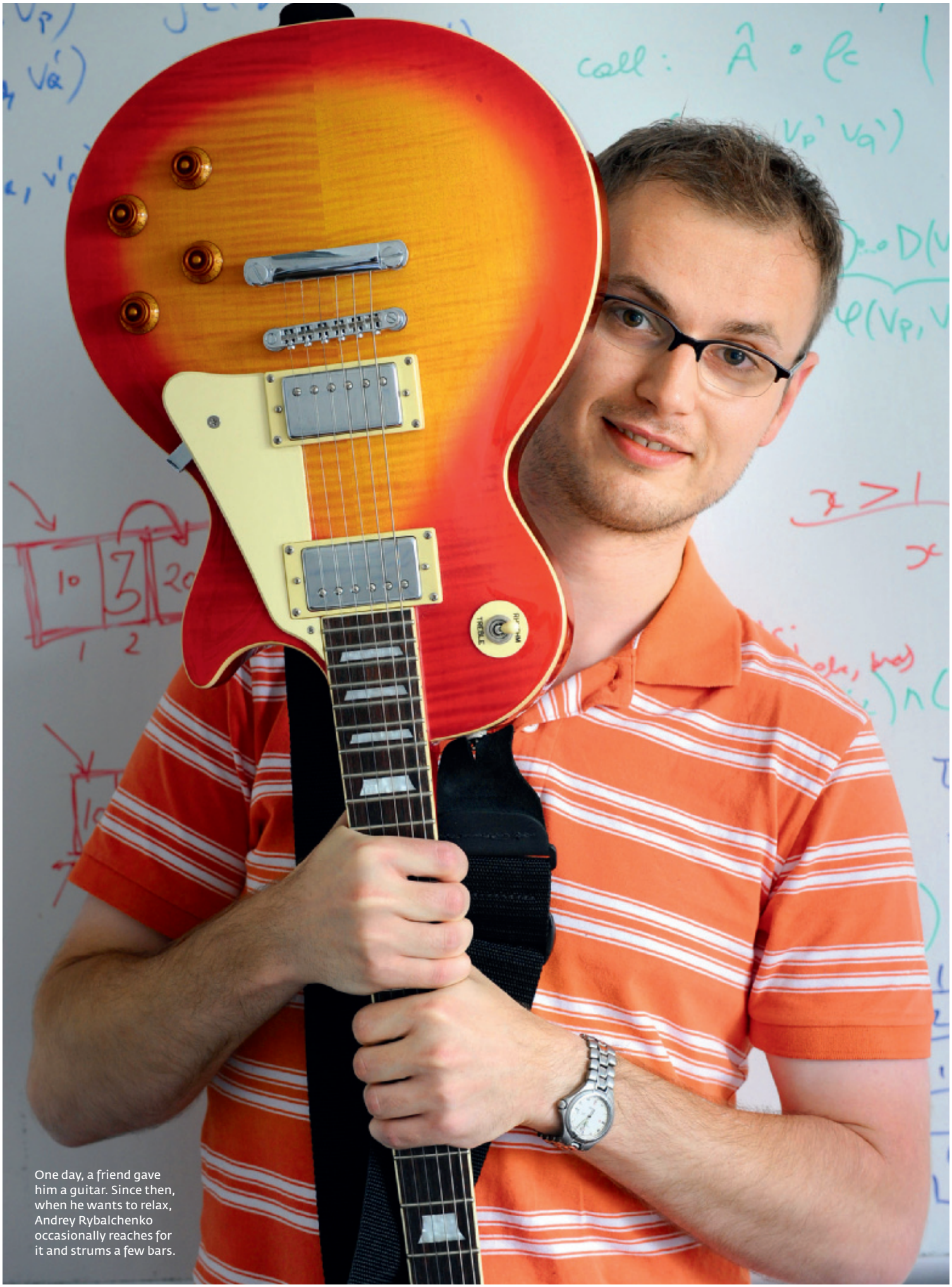


One day, a friend gave him a guitar. Since then, when he wants to relax, Andrey Rybalchenko occasionally reaches for it and strums a few bars.

Tough Tests for **Software**

No, he isn't a nerd! But computers do run his life: 31-year-old **Andrey Rybalchenko**, a scientist at the **Max Planck Institute for Software Systems** in Saarbrücken, develops tools that automatically analyze and optimize programs.

A PORTRAIT BY **UTA DEFFKE**

Andrey Rybalchenko is a computer freak. He doesn't spend his nights playing games, or hacking his way through cyberspace like a lunatic. Nor would one find the nerd's hallmark stacks of empty pizza boxes in his well-lit and very tidy office. Also in many other aspects, the tall young man doesn't quite fit the stereotypical image of the average computer nerd: he is friendly, very communicative, arranges coffee and cake for visitors, and the ping-pong paddles on his shelf tell tales of the friendly round-robin tournaments that take place in the institute basement.

Nevertheless, Andrey Rybalchenko is a computer geek – in his own way. His passion is software – that vast mass of computer code that can operate microelectronic circuits only with "on" or "off," "0" or "1." Software is what breathes life into them and makes them what they are: highly efficient computing devices without which almost nothing in today's world would work – including a train trip to Saarbrücken.

But Rybalchenko doesn't write programs for train control units, automatic teller machines or coffeemakers. His research analyzes software that already exists, or that soon will exist, for these and similar applications. "The programs are intended to carry out very specific tasks, to work efficiently, and of course, to not make any mistakes," says the computer scientist. He develops software tools that automatically analyze and optimize the programs in these respects.

SOFTWARE ERRORS INCUR ENORMOUS COSTS

The Max Planck Society recently dedicated a separate institute in Saarbrücken to meta-research on software. Andrey Rybalchenko began working here, at the Max Planck Institute for Software Systems, two years ago. In his tenure track position, he conducts research into software verification with his own six-person working group.

Given the ubiquity of computing devices, one might think that programming was by now a pretty well run business. But the development of the computer is not only an incredible success story, but also a story of catastrophes great and small. From the dreaded Windows blue screen to the spectacular crashes of Ariane rockets and near-crashes of airplanes, to major power outages like the 2004 blackouts in the US, the consequences of software errors incur enormous costs. That is why around half of the time needed to develop software is spent on testing and debugging.

"Software is the most complex artifact that we routinely produce," says Rybalchenko. "Anyone who thinks that their home computer is a complex monstrosity should realize that the software needed for a modern BMW or Mercedes to drive even a few feet contains more lines of computer code than Windows." And it's no wonder, with 200 microcontrollers managing everything from fuel injection to airbags to heated driver's seats. All of these systems must communicate with each other, exchange data reliably and at precisely the right moment, and they must continue to function even if another component should happen to fail.

A computer is not necessarily a single machine. In distributed computing, for example, large ensembles of processors work together to carry out a single task. And of course this complex system of interactions must be well orchestrated – using software. >

Photo: Frank Vinken

» The computer scientist not only likes to wax philosophical about his science, he is also quick to offer the occasional quote from some of the greats: Tolstoy, Machiavelli, Bill Gates and the pioneers of computer science are just some of the words of wisdom he has on tap.

The researchers are interested in learning how the hardware resources can best be used, how chronological sequences can be optimized, how different computer languages can be reconciled – and, of course, how they can automatically improve the quality of software programs.

WEAKNESS FOR MATH AND PHYSICS, AND LATER FOR COMPUTERS

Why did Andrey Rybalchenko pick precisely this research field? One could say it was chance. Or destiny. "It's like with an ant colony," he says, referring to a passage by Tolstoy, who, in his novel *War and Peace*, compared Russian society with an ant colony. Which steps individuals take and why is just as unfathomable as it is ultimately irrelevant. In the end, it is the whole that counts.

The computer scientist not only likes to wax philosophical about his science, he is also quick to offer the occasional quote from some of the greats: Tolstoy, Machiavelli, Bill Gates and the pioneers of computer science are just some of the words of wisdom he has on tap, and of course also Peter the Great. This predilection for quoting great authors is a result of the classical education he enjoyed in his schooldays, part of which were spent in the Soviet Union.

Andrey Rybalchenko was born in 1978 in Woronesh, an industrial city with a population of nearly one million, 500 kilometers south of Moscow. His father worked as an engineer, his mother as a bank employee. Andrey is their only child.

As long as he can remember, he has had a weakness for mathematics and physics – and at some point, also for computers, which were available at his school. "We watched the development of computers from the early days of Eastern European computing systems to the first cloned PCs to the first Pentium," recalls the computer scientist. But he would certainly not call himself a computer kid – hardly anyone had a personal PC in those days, and games were taboo. What fascinated him even back then was the combination of math and physics tasks and programming.

Andrey attended a school that focused on mathematics and natural sciences. He participated in math and physics olympiads and took correspondence courses at a few major universities. Despite these academic pursuits, he still had time to play soccer in the street and to go skiing and play ice hockey when the roads froze over in winter. And he played guitar: "I was a big fan of blues at the time, and was determined to learn to play it myself," says Rybalchenko. He got his chance when a friend showed up one day and gave him a guitar. He still owns a guitar, and when he wants to relax, he still occasionally reaches for it and strums a few bars.

NO INTEREST IN ALGEBRA FOR ALGEBRA'S SAKE

He has only vague recollections of the period when the political situation in the Soviet Union reached a turning point. That time was marked by economic problems and great uncertainty. Andrey Rybalchenko recalls television images of tanks in front of the White House in Moscow, and the budding

The family couldn't afford an elite university, so Rybalchenko studied at the one in his hometown, Woronesh.

Photo: OH

When he needs a break from his work, the young scientist relaxes with an espresso and the newspaper.

Photo: Frank Vinken

military conflicts in the newly independent republics. "It was no longer possible to sweep everything under the rug," he says.

The fall of the iron curtain and the rise of the Internet opened up new possibilities and awakened longings for the distant realms of the West. But his family could not afford the steep tuition required for him to attend MIT or another top-ranking engineering school in the US. Nor could they afford any of the elite Russian universities in Moscow. So he had to settle for his home town for his first university experience, where he studied mechanical engineering with a focus on computer science – after all, he wanted to study something concrete: "As interesting as it was, I never wanted to explore abstract algebra or logic merely for their own sake."

It was a chance encounter that allowed him to fulfill his desire to see the West. During Christmas break in 1997, Andrey met an old school friend on the street, who talked about his computer science studies in Saarbrücken. Not only were there no tuition fees, but there were also many opportunities to finance the cost of living through interesting student jobs. Following this conversation, Rybalchenko quickly filled out the application, and soon his ticket for Germany was booked.

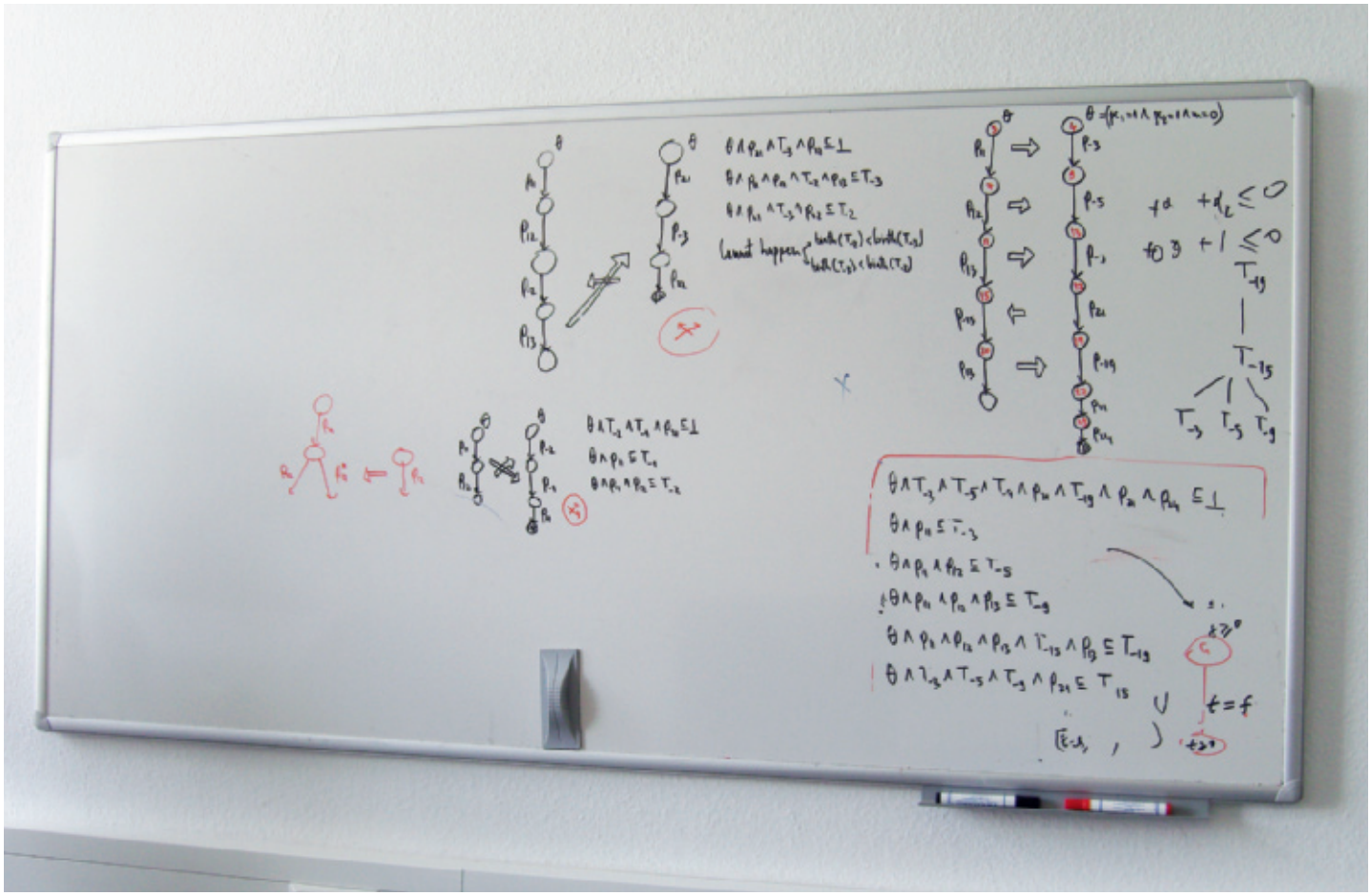
Saarbrücken – that doesn't sound like the "big wide world," or even like MIT. A region with a known flair awaited the young Russian: ailing and defunct mines, and a metallic smell in the air. But the former Montan metropolis also has its attractions. Rybalchenko values the region's cultural diversity, due, in part, to its proximity to France and Luxembourg. The fact that he just happened to land in a bastion of computer science – one that had even since gained some international renown – was purely coincidence. But it was a stroke of luck for the ambitious student.

Toward the end of his studies, he became acquainted with questions of software verification, and with Andreas Podelski at the Max Planck Institute for Computer Science. Podelski happened to be looking for a student for a research project in verification. Rybalchenko took the job, and Podelski later became his Ph.D. advisor. And thus the topic of his dissertation was decided. "The possibility of using scientific methods to examine programs and programming and, in turn, of using further programs to automatically analyze them, is quite fascinating," says Andrey Rybalchenko.

But software engineering is much more complex than structural engineering. Structural engineers can determine the maximum load of their buildings relatively easily, but the limits are less clear for software. Previously, to test a program, a researcher would select a set of possible program inputs, execute the program with those inputs, and then observe the program's behavior. But there is no

above | Exercise strengthens body and mind. That is why, as a matter of principle, Andrey Rybalchenko bikes to work at the Max Planck Institute for Software Systems in Saarbrücken. There, in his tenure track position, he conducts research into software verification with his own six-person working group.

below | Andrey Rybalchenko certainly values the conventional: "In order to understand something correctly, one must explain it to others and discuss it with them – on the whiteboard."



Photos: Frank Vinken (top)/MPI for Software Systems (bottom)

» Although his research is all about computers, his work does not focus on actual computers as tools. Instead, he spends most of his time thinking in quiet solitude, assisted by paper and pencil.

guarantee that this process will identify all possible sources of errors. "And testing every possible case manually is too laborious," says Rybalchenko.

Normally, one would use abstraction – that is, omit unimportant program details to simplify the problem. But finding the right level of abstraction is tricky. Especially for testing so-called liveness properties, this has not yet succeeded. Liveness properties guarantee that desired events occur – for example, that a certain query is executed within the program, or that a calculation terminates and doesn't just get stuck in an endless loop. With abstraction, relevant properties can be lost, and even if they are, it's possible that the event might in fact still occur at some point during the program cycle.

A NEW CLASS OF HELP STATEMENTS

Researchers have been chewing on this problem for decades. "Interesting questions about programs are undecidable!" Andrey Rybalchenko likes to quote this theorem, which acts like a driver for his work. But that just serves to increase the young scientist's ambition. In his doctoral dissertation, he developed new analysis software for testing liveness properties. The approach is based on the theory of an entirely new class of help statements that he formulated. These so-called transition invariants can be generated automatically, and analyze the program bit by bit.

Unlike engineers, who describe continuous processes in nature and machines with the aid of mathematical equations, computer scientists use logic to analyze software, which is based on discrete yes and no statements. This quickly brings them to some very fundamental questions that also occupied the pioneers of computer science in the 1940s and 1950s, like Alan Turing and John von Neumann: What can actually be calculated with a computer, anyway? And which calculations can be carried out efficiently – that is, within an acceptable time frame? "On the one hand, this is an interesting intellectual challenge, but it is also an opportunity to make an enormous contribution to society," says Rybalchenko.

Although his research is all about computers, his work does not rely on using computers as tools. Instead, he spends most of his time thinking in quiet solitude, assisted by paper and pencil and the scientific papers others have written. "And then there is also the whiteboard," the Max Planck researcher stresses, and points to the many and multicolored logic equations, flowcharts and tree diagrams covering the white surface: "In order to understand something correctly, one must explain it to others and discuss it with them – on the whiteboard."

In the end, though, the computer does prove to be a practical aid, allowing the computer scientist to directly check his ideas. "All one has to do is feed all these lines of code into the computer, then the fan kicks in because computing consumes a lot of energy, and in the end, it returns a very simple statement: O.K. – property satisfied. That is truly a great experience," says Rybalchenko excitedly. Of course, it sounds easier than it is. And that isn't the end of the job, either. But it doesn't require a giant particle accelerator, nor must one wait years until the planets line up in just the right configuration.

MEETING A PIONEER IN HIS FIELD

Andrey Rybalchenko was able to test his own findings on liveness properties during his time at the Microsoft research labs in Cambridge, England. Following completion of his Ph.D. dissertation, he spent a few months there as a visiting scientist, developing software to verify Microsoft drivers. "The environment there is also very scientific," says Rybalchenko. "Even back then, I was certain that I wanted to work in research."

And that visit garnered him another very special encounter: One day, he found himself face to face with Sir Tony Hoare. "He is one of the pioneers of our field," says Rybalchenko, recalling his "very British" manner with a grin. In the 1960s, Hoare had developed one of the first computer algorithms, and soon afterwards, had begun to think about the analysis and correctness of programs. He still works for Microsoft now, even in his retirement.

Since Hoare himself had studied at Moscow State University in the late 1950s, he and Rybalchenko even spent some time discussing their ideas in Russian. In Rybalchenko's opinion, the fact that such casual encounters with

There's the bug: Rybalchenko simplifies the search for software errors, which programmers call bugs.

the luminaries and pioneers of the field are possible is one of the things that make his science so appealing.

And in general, he values the flat hierarchies and the marked culture of discussion in the computer science community. It has become something of a second home to him, regardless of where he happens to be located. After all, Andrey Rybalchenko has covered a lot of ground traveling to conferences. Rarely has he been drawn back to Russia. "Traveling there is complicated, and I don't have time for that," he says. Luckily we now have the Internet and satellite television to keep in touch. "But I have since become quite curious, and I would like to discover the country as a tourist one day."

Following a second postdoc position in Lausanne, Andrey Rybalchenko is back in Saarbrücken for the time being. The Max Planck Institute for Software Systems lured him with a tenure track position. "This is an internationally renowned institute – just what every scientist hopes to find. I have the best conditions here," concludes Rybalchenko. This includes the flat hierarchies that make even young scientists feel like accepted colleagues. MIT has long since been forgotten.

AN EYE FOR THE VIRTUAL, BUT ALSO FOR NATURE

His research focuses on the liveness properties of software, but he also has an eye for real live objects: "Programs aren't just for computers. Nature, too, uses programmed processes." In cells, for example, where biochemical reactions depend on the concentration of certain proteins. As with the zeroes and ones in microprocessors, the concentration of proteins in cells can be thought of as a binary system: if the concentration exceeds a threshold value, a reaction is triggered, and if it doesn't, no reaction occurs. "Of course, this becomes interesting only when many cells interact," says Rybalchenko.

Biologists, for example, observe thousands of cells and look to see how cancer can emerge in that ensemble if only a single cell is programmed incorrectly. The huge number of possible combinations of cell interactions results in an extremely complex system, and analyzing such a systems poses the same challenges as the verification of computer programs. "So we want to try, with our logic-based methods, to model the programming of biological cells."

On this topic, however, Rybalchenko's research is still in the very early stages. With verification, he has yet another success story to look back on – a research project that recently received a Best Paper Award: using a new approach that required just one input, it was possible to obtain such important information from the program sequence that the overall examination is eased significantly.

Also hanging on the wall, next to the Best Paper Award, is a group photo from a recent workshop in Turkey: computer scientists against the backdrop of the Mediterranean. The event involved more than just mental acrobatics – windsurfing, for example, is one of the many things on which the Max Planck scientist would like to spend more time. But in view of the jam-packed day-to-day life of a researcher, that, too, is akin to acrobatics: "It's a real dilemma: do I spend the evening in the lab, or do I go to a concert or to play sports? The research

Photo: Frank Vinken

» The first thing on the agenda is a better work-life balance. The holiday he finally planned is a good start.

is so interesting that it's easy to forget everything else, and the competition isn't sleeping."

"CLASSICAL MUSIC – THAT ROCKS"

But Andrey Rybalchenko did manage to get his yellow and orange belt in jujitsu while completing his dissertation, and learn Alpine skiing in Switzerland and surfing on a reservoir lake in Saarland. And he recently scored an autograph from Russian pianist Evgeny Kissin, who gave a concert in Luxembourg. "I love classical music, too, possibly for the wrong reasons, but I think it rocks." When there's not enough time for such excursions, at least the ping-pong table in the basement of the institute offers a welcome change of pace. In the relaxed atmosphere there, they talk about their current work or make plans for getting together after work. Rybalchenko even recently attended a colleague's wedding in his hometown in India. This type of relationship among colleagues is very important to Rybalchenko.

He has no plans yet to start a family of his own: "It will happen when it happens," he says. The first thing on his agenda is a better work-life balance. The holiday he finally planned is a good start. Since windsurfing in Turkey involved swallowing quite a bit of water, he wants to learn it again properly on the sea … ◂