



Research Automation in Aberystwyth, Wales

# Robot Scientists – Return to Paradise

Computer scientists have succeeded in creating your ideal bench colleague: the first machine to independently discover new scientific knowledge. Susanne Dorn reports and reflects on robot 'Adam'.

Times are hard these days. Competition is ubiquitous and job-hunters are calculating and aggressive. Why should it be any different in the life sciences? Here, it seems that the situation will get even worse in the near future, since there is a new super-worker coming onto the research market. May I introduce Adam. He is praised as working harder, faster, more accurately and more effectively than anything seen before. Plus, he is autonomous, clever and, most importantly, purposeful. Furthermore, he is a quiet and discreet colleague, using few words and raising no objections. It seems like Adam is the ideal colleague, with fantastic hard and soft skills that presumably will allow him to produce top-class research. Well, numerous scientists have shown similar initial promise. But Adam is different: the characteristic that really makes him unique is that Adam is a robot.

Okay, admittedly the fact that he is a machine doing various lab jobs won't knock your socks off! Robots are part of everyday research; in the course of automation they tremendously facilitate experiments and science. It is now impossible to imagine life without computers. But what is really special about Adam is that he is the first of his kind to do research on his own, autonomously, without human help or coordination. He is a machine equipped with an enormous helping of artificial intelligence. We have encountered similar species in the movies but Adam has little in common with his humanoid counterparts. His appearance is rather inconspicuous with no blinking eyes or chaotic wire hair. In fact, Adam is a big glass box and his inner workings are made of stand-

ard lab equipment like freezers, incubators, liquid handlers, plate readers and centrifuges. He manages his experiments completely independently, using one of his three gripper arms. Adam works so independently that he only requires a human technician to periodically add laboratory consumables and to remove waste. Most importantly, his brain – the part that makes the whole thing function – is located in four computers. This works using various pieces of software: one to deduce scientific hypotheses, some to decide which experiments to perform to test the observable consequences of his ideas and to plan, design and physically execute them, and still others to record and analyze the data and to relate them to the hypotheses.

## Correct proposals and predictions

Adam's creators, the computer scientists and biologists under Ross King from Aberystwyth University in Wales and the University of Cambridge, UK, developed the robot for basic gene analysis research. His first project was to identify the genes encoding so-called orphan enzymes in *Saccharomyces cerevisiae*, metabolism proteins for which the encoding gene counterparts are so far unknown. First, he took a crash course in molecular biology, cramming all existing information about the genes involved in yeast's metabolism into databases. Then, he started. He formulated and tested 20 hypotheses on 13 orphan enzymes and the genes by which they might be encoded. Performing about 1,000 experiments per day, he pipetted, shook, washed, cloned, incubated, isolated and, finally, drew his conclusions. For instance, he looked at the enzyme 2-aminoadipate:2-

oxoglutarate aminotransferase (2A2OA), known to be involved in the biosynthesis of the amino acid lysine in fungi. Adam proposed, and experimentally confirmed, that the three genes YER152C, YJL060W, and YGL202W encode for that protein. Additionally, he correctly predicted the function of six positive control genes, the enzyme correlates of which are actually not orphans but proteins, for which related genes have been proposed due to empirical evidence. Adam's results were subsequently tested in traditional experiments carried out by his human assistants and 12 of his novel and unsuspected gene-enzyme pairs were confirmed.

## No problems with complexity

But why was Adam successful where humans have so far failed? How could he identify the genetic backgrounds of the orphan enzymes studied, something which has remained indeterminate for such a long time? Complicating factors like gene duplication with a retained overlapping function, enzymes catalyzing more than one reaction and existing annotations might be the guilty parties. While humans are overwhelmed by the complexity of the situation, Adam's strengths are just beginning to show. He is able to unravel the tangled puzzle by using his systematic bioinformatic and quantitative phenotypic analyses.

And the robot scientist did a really good job! In the end, Adam's bosses were so satisfied that they published his work in the April issue of *Science* (*Science* 324:85-9).

But the humans did not just use the super-researcher, they also cared for Adam's welfare. What could be more caring than giving him a wife? Her name? What a question. Since you ask, her name is Eve. Given that Adam has no ribs, how they did it will remain an open question. Nevertheless, she is his mate; just as good – perhaps even more advanced. Her project, however, will focus on the screening of drug candidate molecules.



Adam's 'father' Ross King...

Adam and Eve; a dream team heading for success no doubt. These high fliers are heralding a new age of science. The progenitors of a bold new scientific generation, giving research a true facelift. We can already predict that in just a few years, their progeny will be part of each research group, removing the drudgery of repetitive experiments from the shoulders of lab technicians, doctoral students and postdocs. Being faster than all of those put together and able to perform and coordinate thousands



... and his robot child.

of experiments simultaneously, the exceptional robot researchers will free humans from annoying and time consuming everyday work. Well, all right, one or two mid-dling scientists will be out on their ear when Adam's colleagues appear. But don't worry, researchers of true greatness can never be replaced by machines. So far, Adam is just experienced enough for a junior scientist position, his fathers state. Human seniors will hold their ground, as they are and always will be better at overseeing the big picture of a project. Nevertheless, the robots will also learn new things. The further that they are developed, educated and trained, the more likely it is that they will come up with highly sophisticated ideas.

Yes, there is a glorious and brave new world ahead. Scientific progress will be

overwhelming. The robots will do all the dirty jobs: planning, performing and analyzing the experiments, integrating their results into existing knowledge and automatically continuing with the next logical steps. Their human overseers can only benefit: no stupid student questions, no lazy postdocs to motivate, none of the managerial skills needed to lead a large group of scientists or empathy if a co-worker is unhappy. Just them and one or two Cains or Abels. What a luxury! Group leaders – finally – will find the time to apply themselves to the joyful aspects of science: meeting colleagues, showing up at conferences, presenting their hottest achievements and collecting glory (or at least what a researcher dreams of during his nap at his desk).

However the foreseeable the future sounds now, several issues surrounding the dynamics in modern research groups remain to be clarified. For instance, how will young human scientists demonstrate their genius if not by working night and day for a brilliant doctoral thesis? How will human genius be defined, if they are always topped by a machine? What should human researchers do with their new free time? Serve the robots, providing them with or removing liquid? Will Adam and his team take over some seminars at the university to cover those pesky teaching responsibilities? Will there be any further need for biology students? Or would they better be advised to re-train and become engineers or computer specialists? How to deal with

Adam's results in publications? Should he go down as first author, being the one who did all the experiments? Will Adam listen to profane human problems if there is no one else to go out for a beer with? What, if Adam and Eve get more and more artificially intelligent and start to develop their own idea of good and evil? What if they start to reproduce independently, if they give up cooperation and fight against the human species, if horror movies come true? Questions and questions abound.

#### Mixed prospects

Well, it can be expected that the robot family will come up with a solution to these problems in coming years. However, by then the only thing that we should be prepared for is a second expulsion from Paradise, this time by Adam and Eve themselves.