Oy Robot!

Are we doomed to some postapocalyptic nightmare in which robots rule the planet? Roboticists Henrik Hautop Lund and Rodney Brooks square off.

Open Debate

<<< **HENRIK HAUTOP LUND**
Professor at the University of Southern Denmark's Maersk Institute and former head of the LEGO Lab

RODNEY BROOKS >>>
Director of MIT's Computer Science and Artificial Intelligence Laboratory and cofounder of iRobot Corp.

Resolved: *In the next century, robots will take over the planet.*

Lund: We are very far from the intelligent, autonomous robots known from science fiction. But I see a lot of developments that will make a huge impact on our daily lives in the future. Indeed, we have a responsibility to develop robot technology into some sensible application of high social value (as opposed to the American robotics community, which is guided largely by military funding). For instance, in my university lab and at my Entertainment Robotics company, we are (with various partners) developing robotic spin-offs for teaching creativity in developing countries in Africa, for rehabilitation of elderly people with dementia, for physiotherapy, for playware to fight the obesity problem, and so forth.

Brooks: It all depends on what we mean by "take over" and "planet." If we mean "take over" in the Hollywood sense of robots getting impatient with us humans making bad decisions and deciding that we are redundant (hmmm, reminds me of my teenagers . . .), then I agree—we are not going to see that. However, I think computers have "taken over" our lives in the Western world, and even, but less unpleasantly, the Third World. Robots will do the same.

And now to "planet." Yes, my research group is funded in part by NASA. Why? To develop robots that we can send to the moon and to Mars to prepare habitats for humans before they arrive, and to take care of facilities once humans have left. The robots will be the permanent residents—so they will indeed have taken over.

Lund: It's crucial to understand the relationship between body (hardware) and brain (software). For space exploration, the body may be more important: We would want to pack robotic artifacts for the launch, then allow them to unpack themselves where they are to perform their mission. Such flexibility could be obtained with something like our ATRON modules. A robot might be composed of 100 modules that each can process, communicate with neighbors, and move together. Such a robot can change its own form to adapt to different tasks, such as rescue work after earthquakes.

Brooks: But the limiting factor in such approaches has been the physical strength of the joints; practical robots have relied on large macrostructures to provide strength. Biological systems do not have this limitation, since they are built of systems that rely on tensional integrity, like a buckyball.

Now how does this relate to the question before us: "Will robots take over the planet?" The hard-material version of nanotechnology posits small robots that self-reproduce and then get out of hand. But this nanotechnology faces the problem I described above; there is no evidence (yet) that such machines will work. It is much more likely that atomic-scale robots will have bodies held together with a form of tensional integrity. So most of today's research on multimodule robots (like ATRON) will not be the direction that is ultimately taken as a practical matter.

I think the way forward will see a merger of biological materials and robotics. At our lab, Tom Knight is building microbial robots by splicing standard "parts" into a DNA string, effectively allowing a program to digitally control protein production in the cell. His "robots," based on an E. coli chassis, communicate, move about, and sense their environment. And he can build a million of them overnight.

Read the full text of this email debate at www.fastcompany.com/keyword/opendebate104.

112 FAST COMPANY April 2006

Photography by Erik Refner (Lund); Ben Stechschulte (Brooks)

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Resolved: In the next century, robots will take over the planet!

Henrik Hautop Lund

Professor at the University of Southern Denmark's AdapTronics Group and former head of the LEGO Lab

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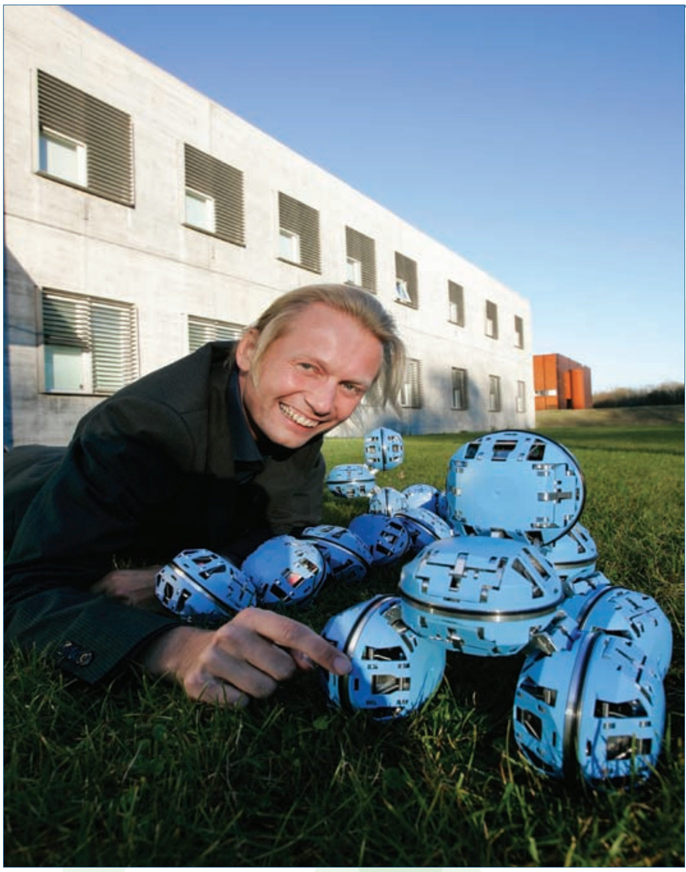


Henrik Hautop and his ATRON robot

Lund:

I cannot imagine such a scenario with robots taking over the planet. In robotic research, we are very far from the intelligent autonomous robots known from science fiction. On the other hand, I see a lot of spin-offs from robot development that will make a huge impact on our daily life in future. Indeed, I believe that we as robot scientists and developers have a responsibility to develop robot technology into some sensible application of high social value. Here I am thinking of the European tradition of looking at edutainment robotics, neuroscience and robotic prostheses, etc. whereas I see an American robotic community to a large degree guided by the military and its funding schemes. I think that this will guide the robot developments that we make, and I would myself opt for the developments that can have a clear social impact. For instance, in my university lab and my Entertainment Robotics company ((www.e-robot.dk), we are currently developing robotic spin-offs for teaching creativity in developing countries in Africa, for rehabilitation of elderly with dementia (together with University of Siena), for physiotherapy (together with Funen Hospital), for playware to fight the obesity problem together with Europe's largest producer of playgrounds KOMPAN (and Danish University of Education), and so forth. I think that we as some of the influential experts in the field have a responsibility to guide the development of the future, but I see a lot of American robotic development being guided by other incentives, such as the military funding.

THE ATRON MODULES PRESENTED TO HM QUEEN MARGRETHE II OF DENMARK

Brooks:

I think it all depends on what we mean by "take over" and "planet."

If we mean "take over" in the Hollywood sense of the robots getting impatient with us humans making bad decisions, feeling like we are not giving them their due, and deciding that we are redundant (hmmm, reminds me of my teenagers…) and that their world will be better off without us, then I agree--we are not going to see that, despite all the movies we have seen. "But I've seen it in so many movies"--well in real life we're not always seeing ghosts, fighting aliens, or driving flying cars, all of which are staples of Hollywood predictions. Nor will we see the robots rise up against us.

However, compared to when I was born in 1954, I think computers have "taken over" our lives in the western world, and even, but less unpleasantly, the third world. When I was born there were hardly any computers in the world, and none at all in the city of more than half a million (at the time) where I first saw light (and there were no other cities at all within 500 miles). Now when I am out of the house I always have pockets full of microprocesors in the form of two telephones, one GSM and one WiFi, that will route voice messages to me from anywhere in the world at any instant. When I drive my eight year old car most of what I do in the control sense is modulated by embedded microprocessors, especially the brakes, fortunately, as I live on a very icy street. The radio that plays in my car is packed with microprocessors, handling the audio data digitally. And in my breast pocket at all times are two tiny little 1GB memory sticks each with a microprocessor in them. In my house and at work I am surrounded by computers--some unnetworked such as the ones running my bedside clock, by fridge, and my coffee machine, and many networked, such as the ones in my phones, in the WiFi repeaters, in my cable TV set top box, and the six laptops that every member of my family (except the dogs) use most hours of the day. The computers have taken over my life. I spend my day interacting with them. And when I was in Mumbai last week I saw day laborers working in completely traditional ways with woven baskets for digging soil and transporting rocks across the worksite, but reaching into their sarees to take telephone calls--computer driven and mediated communication.

Computers have taken over our planet in a mere fifty years.

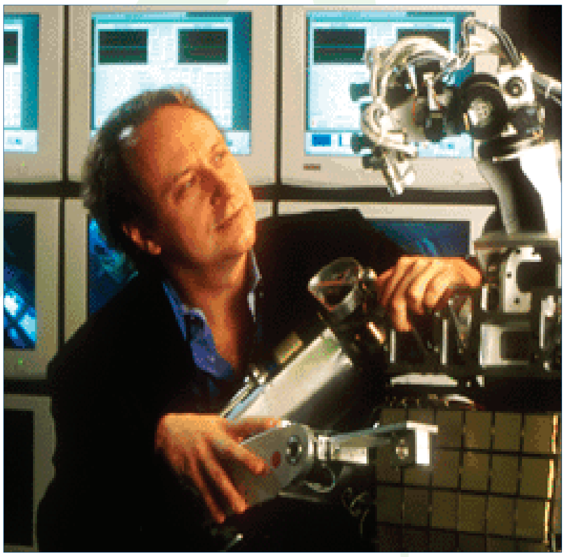
Robots will do the same.

And now to "planet." Which planet exactly? Henrik is a little

Above left: The PackBot battlefield robot.from iRobot.
Above right: The iRobot Scooba floor washing robot.

behind the times on understanding U.S. funding--in the large scale computer science and artificial intelligence lab that I direct, with 93 faculty members, 470 graduate students, and another 270 staff and visitors, we were funded over 90% by the defense department ten years ago. Today that number is less than 25%. In my own little research group we are completely funded by a Japanese company, a European company, and NASA.

And what is the NASA funding for? To develop robot technology to the point where we can send robots to the Moon and Mars to prepare habitats for humans before they arrive, to assist humans while they are living on the surface, and to take care of the facilities once the humans have left. The robots will be the permanent residents of the planets and the humans will be transient visitors. So for the other planets of our solar system the robots will indeed have taken them over. Now perhaps we might want to debate the speed of developments in the future, and how "cognitive" these robots may be.



Above: Rodney Brooks and his COG robot.

Above: Modular robotic building blocks, Playware tiles, developed as the playground of tomorrow to physically activate children e.g. to fight obesity or for therapy.

Left: Modular robotic building blocks, African I-BLOCKS, used at Ilembula Hospital, Tanzania.

Lund:

Certainly, we have to agree on which planet we are talking about. My inclination is to make robotic applications to solve problems for our population on this planet. There are plenty of problems in the daily life of many people on this planet where robotic spin-off application can help in the same way as the computer spin-offs are influencing our daily life as you mention them. I am thinking of the huge potential in cognitive rehabilitation, physical rehabilitation, fighting obesity, surgical robotics, releasing creative potential amongst people in developing countries, entertainment and services in general. I think that there are so many potentials for the spin-off applications from the robotic research and development that may help a lot of people in their daily life that we as expert roboticists have a responsibility to help this development on its way.

But of course there is huge potential in utilizing robotics for space exploration. I think that it poses an interesting challenge on robotics in what kind of robotics is necessary and suitable for the different kinds of space explorations, and how cognitive these robots could/should be. There are many different views on this issue. I believe that it is crucial to use a thorough understanding of the relationship between the body and the brain (between the hardware and software control). For space exploration, we can imagine that physical reconfiguration (change of the body) may play even a larger role than control adaptivity (change of the brain) - we would probably like to pack robotic artifacts as much as possible for the launch and then allow the robots to unpack themselves (physically reconfigure) at the place where they are to perform their mission. This demands flexibility of the physical body of the robot. Such flexibility can be obtained with modular robots for self-reconfiguration such as our ATRON modules. A robot may be composed of e.g. 100 such ATRON modules that each contains processing, communication to neighbours, mobility on each other, etc - a bit like cells that can attract each other, perform cell migration, cell death, etc. A robot composed of such modules can change its own physical form to physically adapt to the different tasks that are to be performed. But this could even be used here on our planet, e.g. for rescue work under collapsed buildings after earthquakes. When using this kind of robot for the rescue work, the robot may drive to the disaster area, transform itself to a crawler to proceed over rough terrain, and if it finds a hole in the piles of bricks it may transform itself into a snake to wind into the hole and possibly find air holes under the collapsed buildings where it may transform itself into columns to sustain the building until survivors can be rescued.

I believe that understanding the role of the body is crucial for the scientific understanding of intelligence and for future robot applications, as explained above. Also biomimetic robotics often shows that the right morphology may allow a much simpler control than originally hypothesized in pure behavioral biological work. For instance, we showed how the right ears morphology of female crickets may allow the cricket to have a much simpler neural control for obtaining phonotaxis behaviour before the mating act than was originally hypothesised - because there was an exact match between the three 'B's: the body, the brain, and the behaviour.

So, in order to understand intelligence and cognition, we need to look also at the contribution of the body, and robotics may provide an excellent scientific testing ground for building such an understanding. Or what do you think? Can intelligence be understood in isolation from the body?

Brooks:

As you know my whole robotics career has been based on the idea that the role of the body is crucial for understanding both animal/human intelligence and for designing robots. I have experimented with self-reconfiguring modules, originally for MITI (Japan) in the early nineties to develop robots that could crawl through 8mm holes into nuclear reactor vessels then reconfigure themselves in order to carry out inspection and maintenance. The limiting factor in all such approaches to date has been the physical strength of the joints, and practical robots have had to rely on large macrostructures, on the order of the size of the robot, to give it adequate strength. We see however that biological systems do not have this same limitation, but neither are they built out of small modules that require strong bonds. Rather they are built out of systems that rely on "tensegrity," or tensional integrity. Tensional forces build structures that are both strong and arbitrarily bigger than their largest rigid components. I think that this might be the way forward for building robots out of smaller units.

Now, how does this relate to the question before us? "Will robots take over the planet?" The hard version of nanotechnology posits small robots that self-reproduce and then get out of hand and turn the world into "grey goo." But this form of nanotechnology tries to mimic the macro scale machines that we have at the atomic level and there is no evidence (yet) that such machines will work. Instead I think it is much more likely that very small, atomic scale, robots will have bodies that are very different from our macro scale robots, and most likely will be held together with a form of tensegrity. So I think that most of today's research on multi-module robots will not be the direction that is ultimately taken as a practical matter. Bodies matter, as that is where physics gets to play its role.

I think that the way forward will see a merger of biological materials and robotics. Already people are putting mechanical systems inside their bodies, ranging from simple joint replacements to complex devices interfacing to their neurons, such as in cochlear implants for people who go deaf due to cochlear damage. On the other side, at our lab Tom Knight is building microbial robots, where he splices standard "parts" into a DNA string, so that the normal RNA transcription mechanism effectively allows a program to have digital control over protein production inside the cell. His "robots," based on E. Coli as their chassis, can communicate with each other, move about, signal the outside world, and sense their environments. And he can build a million million of them overnight. Green goo, not grey goo!

WWW.AI.MIT.EDU

WWW.ADAPTRONICS.DK

Lund:

Yes, the ATRON modules distinguish themselves from other such modular robots by the very strong connections, which make it feasible to make practical applications. A number of other systems have shown the concept of self-reconfiguration, but often had practical problems with weak connections (e.g. based on different magnetic systems), and hence scaling-up problems. The ATRON modules are modeled from the oxygen atoms ReO_3 connections, which give point-to-point connections, but with a mechanical emulation of surface-to-surface connection in three points, we achieve very strong connections. Therefore, it now seems to become feasible to make practical applications with self-reconfigurable robots. At the same time, we can make the shape transformations at a speed that makes it possible to use this capability in real world applications. Also for other modular robotic systems for practical applications such as the playware playgrounds, the African I-BLOCKS, and Light & Sound Cylinders for elderly with dementia, we see the importance of the connection system, which always is a major challenge, even when the users perform the reconfigurations. This is the case for practical applications of today.

But where do we go in future? I agree with you Rod that the bio-inspired approach will play a huge role in future, and that, for example, the development of new "soft" material for robotics will be one of the largest revolutions seen in robotics. With new biomaterials and units on a much smaller scale, there will be new control challenges that further enhance the importance of understanding the relationship between control, morphology, material, elasticity, energy use, etc. At some point, we will be able to create soft robots with much more flexible bodies than those "metallic" robots that most people think of today. I think that the understanding of the right balance between these defining components of the robot behavior, and hence also the optimization of material and energy use is amongst the greatest research challenges in robotics, in order for us to create soft robots.