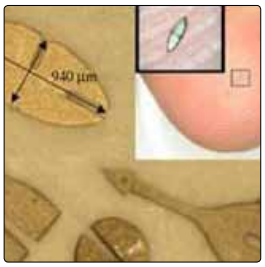
ROBOTS FOR SCIENTISTS, ROBOTS AS SCIENTISTS

HUMAN-MACHINE COLLABORATIVE RESEARCH LEADS TO SCIENTIFIC ENLIGHTENMENT

In an interview about applications of machine intelligence in science, University of Chicago mathematical biologist Andrey Rzhetsky forecasted that the role of human scientists may eventually be "to do the programming, and make sure the robot has enough reagents." Rzhetsky created software that analyzes millions of scientific papers to make hypotheses in genetics research. Efforts of this type point to a shift from science as something that humans do, to a collaboration between human and machine. As software for science improves and robots become more capable of autonomous, safe, and precise behavior in structured and unstructured en\vironments, a new Enlightenment may emerge where the science of robotics leads to robotic scientists.

UNDERSTANDING HUMANS: Mapping the Terrain of Human Biology

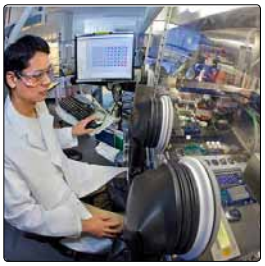
Robotized science is faciliating a deeper understanding of ourselves. Automated laboratories accelerate drug discovery, and microrobots allow us to explore our own bodies. Robots are helping scientists study every human biological system, from genetic building blocks to how the complex electrochemical processes in our brains make us who we are.



Source: http://www.iris.ethz.ch/msrl/research/micro/

Microrobots for interior research missions

Miniscule robots explore molecular structures and cellular systems in the human body.



Source: http://www.physorg.com/news191531551.html

A nanocrystal-producing robot

A robot called WANDA, developed at Berkeley Lab's Molecular Foundry, enables the optimization and mass production of nanocrystals used to tag human cells for study.

Source:http://scan.oxfordjournals.org/content/early/2010/02/28/scan.nsq019.abstract

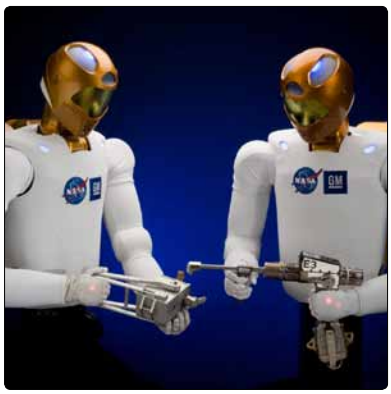
Brain scans reveal how humanoid robots trigger our emotions

Studies suggest that people process emotions shown by robotic systems in much the same way as those of other humans.

THE FUTURE OF HUMAN-MACHINE INTERACTION

AUGMENTING HUMANS: Workmates in the Lab and Outside

In many laboratories, robots handle hazardous tasks or the drudge work of performing endless chemical tests or recording every tedious detail of biological experiments long after the researchers have gone home. As robots become nimble enough for unstructured environments, including the sky, they will become helpful workmates in the real world and beyond.



Source: http://www.nasa.gov/topics/technology/features/robonaut.html

Robotic assistant in space

Developed by NASA and GM, the human-like Robonaut2 will work side by side with humans as a permanent resident of the International Space Station.

Source: http://www.glerl.noaa.gov/res/Task_rpts/2008/eosleshkevich09-4.html

Monitoring nature

NASA and NOAA use autonomous remotely directed aircraft to monitor harmful algae blooms in Lake Erie.

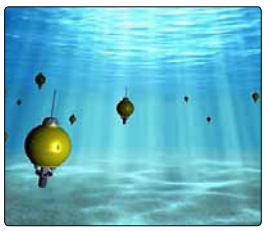
Source: http://www-robotics.jpl.nasa.gov/systems/system.cfm?System=11

Heavy lifting on the moon

The ATHLETE rover prototyped at the Jet Propulsion Laboratory is a heavy-lift utility vehicle to support exploration of the lunar surface.

AUTOMATING TASKS: Science at the Ends of the Earth and Human Abilities

From the distant reaches of our solar system to the deepest crevices of the ocean floor, there are myriad places where it wouldn't be practical to send people. In those cases, the best human for the job will often be a robot. Meanwhile, the processing prowess of embodied computer intelligence will be brought to bear on novel scientific problems, even without our intervention.



Source: http://scrippsnews.ucsd.edu/Releases/?releaseID=1031

Oceanic exploration

Swarms of autonomous underwater explorers (AUEs) being developed by the Scripps Institute of Oceanography will scour the oceans and enable dense sampling at small scales.

Source: http://www.aber.ac.uk/en/news/archive/2010/01/title-83802-en.html

Novel experiments in the lab

Adam, a robot scientist developed at the University of Wales at Aberystwyth, is the first robot to have "discovered new scientific knowledge" in autonomous experiments on baker's yeast.

Source:http://blogs.nature.com/news/thegreatbeyond/2010/04/deepest_deep_sea_vents_found.html

Robot discovery of deep sea vents

A robot exploring the deep ocean off the Cayman Islands discovered the deepest underwater hydrothermal vents ever known, teeming with strange life.

FORECAST

Robots will shift from their role as laboratory lineworkers to scientific collaborators. As extensions of humans, they will be used to gather experimental data in locations and at scales that are unavailable to or impractical for us. Outfitted with emerging sensor technology, they will become like ubiquitous microscopes, keeping a constant watch on the natural world(s). Eventually, they will carry the scientific method forward on their own, making discoveries that will be evaluated by peers, both human and machine.

(1) Assembly-line science

The scientific method will be programmable, and laboratories will become science factories. Even the most basic research will be automated, with individual and networked robots hypothesizing, conducting experiments, and instantly sharing results online for review.

(2) Armchair field research

Already, wireless sensor networks consisting of hundreds or thousands of individual nodes have emerged as a new kind of instrument capable of gathering great amounts of data that can then be aggregated and analyzed. Robots—from telerobotic rovers to autonomous air vehicles to tiny "robugs"—make those sensors mobile, providing scientists back home with a continuous stream of granular information as they move through their environments.

(3) Computer peer reviews

Rivers of sensor data and new capabilities for robots to actually perform science will lead to an explosion of scientific studies. The result is that humans will be unable to keep up with experiment results. Statistical analysis combined with machine intelligence and the semantic Web will yield automated systems to separate the wheat from the chaff before humans make the final call on validity. For a while, anyway.

WHY IS THIS IMPORTANT?

Like art, philosophy, and religion, science has always been a decidedly human pursuit. But as robots advance in physical prowess and processing capabilities, their unique skills can be harnessed for the advancement of knowledge. And as they move from helpful workmates to collaborators or even peers, the floodgates of scientific understanding may start to open over the next decade.

RESOURCES

- LabAutopedia, a project of the Society for Laboratory Automation and Screening, is an information clearinghouse and community for laboratory automation. **http://www.labautopedia.org**
- NASA's Robotics Alliance Project was created as a human, technical, and programmatic resource on robotics capabilities. **http://robotics.nasa.gov/**
- "The Automation of Science" describes a robotic approach to the scientific method and recording of experiments, as exemplified by Adam, the robot scientist that did autonomous experiments on baker's yeast. **http://www.sciencemag.org/cgi/content/abstract/324/5923/85**
- "The Future of Robot Scientists" by Brandon Keim (*Wired* magazine, July 22, 2010) is an interview with Andrey Rzhetsky about the intersection of articifical intelligence and science. **http://www.wired.com/wiredscience/2010/07/robot-scientist/**
- Advances in robotic submarines and flying vehicles, some with applications in science, are the focus of the Autonomous Undersea Vehicle Applications Center (http://auvac.org/) and the Association for Unmanned Vehicle Systems International **(http://www.auvsi.org)**, respectively.

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