Adriano Cavalcanti on Medical Nanorobotics Feasibility

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MEDICAL NANOROBOTICS FEASIBILITY

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In November, *Robotics Today* published an invited extended nanorobotics tutorial (23 pages) with many technical details on aspects related to medical nanorobots development (1). The work addressed questions about the feasibility of nanorobotics, such as motion control, communication, surrounding means interaction, and biocompatibility. It described as well the many benefits nanorobots may provide through the development of new biomedical treatments. We decided to ask Adriano Cavalcanti his opinion about what people may expect from nanorobotics.

New Technologies

The film Fantastic Voyage is quite often associated with nanorobots being used to combat health problems. Will advances in nanotechnology enable nanorobots?

Cavalcanti: Many times science fiction is in fact inspired by reality or based on scientific discussions. For example, Jules Verne's *From the Earth to the Moon* (1865) (2) described travel to the moon, and was inspired from real developments in astrophysics from that period (3). In the year when that book was written, travel could be thought of as impossible for many people. However, now our society is planning to travel to Mars, and most recently has sent autonomous robots to explore the red planet (4). Also during the 19th century, many scientists thought that never would it be possible to determine a star's chemical composition. However, in the 20th century, spectrometry using quantum physics was successfully applied to determine their composition.

In 1966, *Fantastic Voyage* (5) was influenced and inspired partially by real and polemic discussions emerging from statements by the physicist and Nobel prize winner Richard P. Feynman. Feynman had announced the feasibility of nanotechnology in 1959 (6), where the manufacturing of nanomachines could be expected as a quite natural result of advances in technology. Indeed, the speed of new developments is growing faster than ever for these technologies.

Manufacturing Nanorobots

What steps must be achieved to build a nanorobot for human medical use?

Cavalcanti: Manufacturing nanorobots requires advances in diamondoid rigid materials (7). This technology has been demonstrated as feasible, and the manufacturing of nanodevices has been growing in recent years (8). Diamondoid manufacturing is moving step by step, and we are acquiring the requisite understanding to be moving towards manufacturing robots in sizes comparable to bacteria.

For example, a few months ago the first mobile robot was build that measures 60 microns by 250 microns (9). At this scale you can begin to envision in the coming years robot sizes decreasing rapidly to 100 microns, and then to 50 microns, and so forth.

An Intel prototype 90-nm process facility has already produced a fully functional 52 Mb SRAM with transistor gate lengths of 50 nm and SRAM cell sizes of just 1um^2, or roughly half the cell size of today's most advanced SRAMs (10). This downscaling will continue, according to the Semiconductor Industry Association's roadmap. By 2016, high-performance ICs will contain more than 8.8 billion transistors in a 280 mm^2 area - more than 25 times as many as on today's chips built with 130-nm feature sizes.

Inside the human body you have small vessels, 30-60 microns in diameter; therefore, you can see it is quite natural to expect the first nanorobots in the next 10 years (11).

Nanotechnology for Medicine

At this time does there exist any human or animal laboratory trials?

Cavalcanti: Indeed, there are many fully functional nanodevices built, such as motors, sensors, biomolecular computing, and nanotransistors (12). At the moment the main challenge is to integrate the several parts of distinct existing nanodevices into a controllable nanorobot. To achieve that, there are several research teams around the globe working in collaboration through interdisciplinary projects, where the application of computational simulations are being used to help as a valuable tool for testability and system integration. Overall, assuring suitable control over such nanomachines is one of the challenging issues to enable nanorobots, and actually you can evaluate it through computational nanomechatronics techniques.

Using nanorobots in human beings will be done after several hundreds of tests carried out in minimal details first with laboratory mice (13). Indeed, this long testing investigation process is usually done for any new biomedical technology in development. Actually, you have the successful use of nanoshells being tested in mice for the fight against cancer (14). The use of nanoshells results from the application of advances in nanotechnology, and is showing very positive results as a kind of nanomedicine approach. With the progressive development towards nanorobots, we may expect even more formidable benefits in health care.

Customized Requirements

What will be required from a nanorobot to operate in a human body?

Cavalcanti: To be most effective, the ideal length of nanorobots should be no larger than 3 microns in diameter. The nanorobot must have efficient transducers and actuators, with low computational cost, and effectively be able to interact with its surroundings once inside the human body. Therefore, the nanorobot should contain an embedded integrated system required to effectively respond in real time with this environment. Hence, the nanorobot behaviors are expected to respond using motors for locomotion, when such motion control activation becomes necessary due to some kind of biomedical intervention. Nanorobot sensor-based control could be achieved through chemical or thermal nanosensors (15).

Using Nanorobots

Can you foresee patients accepting nanorobots for use inside their bodies?

Cavalcanti: Any medicament to be used in human beings must first be approved after a long set of tests in the laboratory; it doesn't matter whether it is a traditional medicament or a new nanotechnology-based approach for nanomedicine (16). Once good results have been demonstrated with hundreds of laboratory trials, and even more clinical tests, we may become naturally more confident and comfortable with methods that may help relieve people's suffering. It is natural to expect people to adopt proven biomedical technologies in their everyday life, including nanoshells, DNA based nanomedicine, as well as nanorobots.

Adriano Cavalcanti is Chairman and CEO of Center for Automation in Nanobiotech (CAN).

As a CEO and Research Scientist, Cavalcanti has participated in several joint work collaborations for the fast development of Nanotechnology and Biomolecular Engineering Automation. His research activities address various approaches to designing effective nanorobotics and nanosystems automation. He has been also developing works on several research projects related to autonomous systems, scientific visualization and physically based simulation. Among other projects, he is also working through the publication of two new books in Nanorobotics, and preparing to commercialize the software Nanorobot Control Design (NCD) as a valuable tool for Nanotechnologists, Engineers, and Machine Designers.

His research interests include:

- Commercially Nanosystems Devices and Solutions
- Robotics and Nanobiotechnology (NEMS)
- Computational Nanomechatronics for Medicine
- Computer Graphics for Nanoassembly Automation

Center for Automation in Nanobiotech (CAN) -- created in 2004 through the collaboration of private funds. CAN as a dynamic company focuses on investigation of new paradigms for innovation in systems and automation design.

CAN main thrust and aim is the development of practical and useful nanobiotechnology systems and devices that may benefit people around the globe with biomedical engineering advances.

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