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On the market in 10 years

Nanorobot pioneer reveals status of simulator, stem cell work

By Jane Salodof MacNeil

Pedal back to 1966, and a miniaturized medical repair team caroming through the blood stream was the stuff of science fiction. Today the premise explored in the movie Fantastic Voyage is the stuff of nanotechnology, as scientists race to build nanorobots that can diagnose and heal the sick from within the human body.

Human guinea pigs are a long way off, however. Researchers need a way to design, test and refine nanorobots in real-life clinical conditions before they can hope to take nanorobots into the clinic.

Enter Adriano Cavalcanti, PhD, and his colleagues in the School of Electrical and Computer Engineering at the University of Campinas in Brazil. They have designed a Nanorobot Control Design (NCD) simulator on which they are already exploring applications in coronary disease and the use of stem cells to treat diabetes.

At the end of this month, Cavalcanti will describe this ongoing work toward making nanorobots viable in a tutorial at the American Society of Mechanical Engineers (ASME)'s Design Engineering Technical Conference in Salt Lake City. In advance of that presentation, *NanoBiotech News* interviewed him about his own work and why he believes the field will produce the first working nanorobots within the next 10 years. The Q&A follows:

What is the NCD simulator?

Cavalcanti: The NCD is software comprising several modules that simulate the physical conditions, run the nanorobot control programs determining their actions, provide a visual display of the environment in 3D, and record the history of nanorobot behaviors for later analysis.

Our main thrust is toward implementing a practical, effective architecture and a scientifically valuable tool to enable investigation of nanorobot design, control, and automation. The range of applications envisioned is exciting, and a broad core of study cases is coming up. The possibility to customize code for new investigations is also a positive feature in the software.

What will be new in your presentation in Salt Lake City?

Cavalcanti: The NCD has a modular architecture, and we are increasing gradually its complexity and the environment parameters -- as well as the different investigations in biomedical engineering applications. The work at the ASME conference will focus on the automation of nanorobots applied to controlling chemical concentrations for a 3D workspace monitored by nanorobots.

We are planning to include some new screen shots from the simulator. For example, in the coming months we will disclose the results from new work applying nanorobots to coronary problems, as well as a detailed investigation into nanorobot communication techniques. These new results will be fully available very soon with others we have previously published at www.nanorobotdesign.com.

Why are computer-generated models necessary to the development of nanorobots?

Cavalcanti: The development of nanorobots is an emerging field with many open issues. Simulation is an essential tool for exploring alternatives in the organization, configuration, motion planning, and control of nanodevices exploring the human body. Simulation can include various levels of detail, giving a trade-off between physical accuracy and the ability to control large numbers of nanorobots over relevant time scales with reasonable computational effort.

Another advantage is that simulation can be done in advance of direct experimentation. Controlling large numbers of nanorobots is very challenging. It is most efficient to develop the control technology in tandem with the fabrication technologies, so that when we are able to build these devices, we will already have a good background in how to control them.

Hence, the design and the development of complex nanosystems with high performance can be well analyzed and addressed via simulation to help pave the way for future use of nanorobots in biomedical engineering problems. In vitro experimentation is at present possible only on the materials we expect to use in the fabrication of nanorobots -- and not on entire nanorobots, which are still being developed.

What are the challenges to development of medical nanorobots?

Cavalcanti: The main challenge is the need to find a method for building complex devices to molecular precision. This is easiest in the biological realm, where biological nanorobots using genetic cassettes inserted into minimalist microorganisms (~250 genes) are already in fast development using the methods of synthetic biology.

More complex and capable medical nanorobots (www.nanomedicine.com) fabricated from diamondoid or other similarly rigid materials await mainly our ability to do positional mechanosynthesis. Diamond mechanosynthesis has been shown to be feasible in numerous recently published papers and books (foresight.org/stage2/mechsynthbib.html). There are theoretical proposals to create the first experimental tools for diamond mechanosynthesis, and mechanosynthesis using individual silicon atoms has already been demonstrated experimentally.

You have suggested the first applications will be available in 10 years' time. Why is this a realistic timetable?

Cavalcanti: Developments in the field of biomolecular computing have demonstrated the feasibility of processing logic tasks by biocomputers, a promising first step toward building future nanoprocessors with increasing complexity. There has been progress in building biosensors and nanokinetic devices, which also may be required to enable nanorobots' operations and locomotion. Classical objections related to the feasibility of nanotechnology have been considered and resolved, and discussions of techniques for manufacturing nanodevices are appearing in the literature with increasing frequency.

Actually, the manufacturing of nanotransistors and nanodevices is being pursued gradually with remarkable successes. For example, by 2016 high-performance integrated circuits (ICs) will contain more than 8.8 billion transistors in a 280 mm area -- more than 25 times as many as on today's chips built with 130 nm feature sizes.

At the present rate of progress, the first biological nanorobots should be available within five years or less. More sophisticated nanorobots will naturally appear through the development of diamondoid mechanosynthesis and structures. It will also be at least five years until diamond mechanosynthesis can be demonstrated in the lab, and at least five years after before any significant diamondoid structures can be built to specifications. In both cases, we will need proven control methodologies to be available. We can best prepare by doing simulations today.

You have a paper in preparation on design of nanorobot control simulation for stem cell manipulation. Can you tell us about this work?

Cavalcanti: We have a set of works in development for stem cells. The first announced work is to get an overview of possible approaches to using nanorobots to recognize and capture bone-marrow stem cells for medical applications. The second work announced recently is an applied study, where nanorobots inject bone marrow stem cells to treat diabetes.

Nowadays we may see stem cells and nanorobots as one of the most intriguing fields of research, where the going advances in both fields together have a spectacular synergetic impact on our future life span.

Do you have any plans to commercialize your work?

Cavalcanti: Considering the importance of nanorobot control, design and manufacturing, and observing the possible applications that nanorobots face, we plan to commercialize the system. Probably a first trial version could be included in one of the books that we are preparing. After that, we have also a project to disclose a more detailed NCD version with a module that could permit users to define specific parameters and load 3D models easily and more friendly.

As a research scientist, the plan is gradually to open a research center that could enable a growing technical international network exchange with private companies, research institutes and universities. This could be a practical way to enable investors to participate in the development of commercial nanobiotechnology systems and devices that may benefit people around the globe with biomedical engineering advances.

What is your next step?

Cavalcanti: A keen observer could visualize with reasonable acuity that our society lives in a remarkable age, where bridges for the future are being constructed and pursued step by step. Today we can produce knowledge and technical advances in unbelievable speed, enabled by the actual computers as ancillary facilities. In this scenery, nanobiotechnology and robotics could be viewed as breakthroughs for the very near revolution that we are going to produce in human history.

My aim is to keep working on implementation of new concepts and investigation of control and design of nanorobots, focusing on the fast development of nanotechnology with its applications in medicine and biotechnology. The next possible steps could be the joint investigation of nanorobots and nanoelectronics. With coming important technological developments, their link is very interesting -- it is possible that nanorobots could be composed by nanolectronics as well as that nanoelectronics and devices could be manufactured by nanorobots.

We have a set of projects and works on the way. For example, we are making extensive investigations into nanorobot designs, such as motion strategies for low energy consumption, nanorobot decentralized control techniques, and collective behavior design in face of biomedical parameters for specific cases, just to quote a few.

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