Bio-Nanorobotics of Nanotechnology :

Biological flavour of Nanorobotics

The present manufacturing technology is based on creating the objects using techniques such as cutting, carving, molding and welding of materials, which is generally knows as 'top down approach'. For example if we want to make a car body, we have to press the sheet metal using metal forming machines to get the desired shape. In Feynman's talk he mentioned the concept of 'bottom up approach' in which atomic level components are used for manufacturing.

Fig 1 Robert Feynman

Introduction

When talking about *nanotechnology,* it is essential to mention about the history of the nanotechnology. About half a century ago, in 1959, Nobel Prize-wining physicist Richard Feynman first introduced the concept of nanotechnology.

What is nanotechnology?

Before discussing Feynman's new concept a word must be mentioned about the current manufacturing technology. The present manufacturing technology is based on creating the objects using techniques such as cutting, carving, molding and welding of materials, which is generally knows as 'top down approach'. For example if we want to make a car body, we have to press the sheet metal using metal forming machines to get the desired shape. In Feynman's talk he mentioned the concept of 'bottom up approach' in which atomic level components are used for manufacturing.

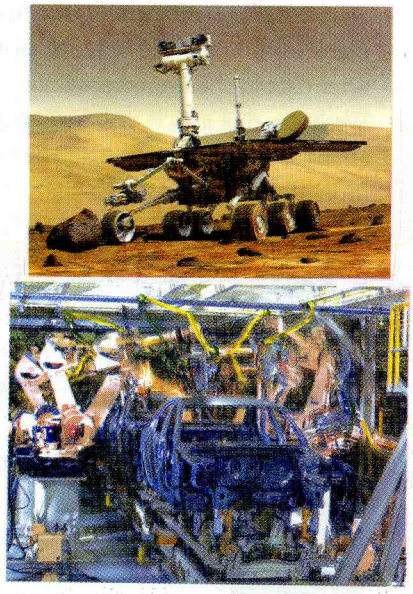


Fig 2 Mass Rover developed for mass exploration (upper), and Robots in car manufacturing plant (lower)

In this approach, the machines are made up of components of single molecules, which are held together by covalent forces that are far stronger than the forces that hold together macro-scale components. Using this approach it is possible to make devices that cannot be achieved due to limitations of the traditional methods.

Current progress of nanotechnology

About four decades after the introduction of the concept, scientists throughout the world are interested about developing nano (10^{-9}) scale devices, which can be used to do tasks that cannot be achieved by classical methods. The introduction of **smart materials** is one of the applications of nanotechnology.

For example, in skyscrapers, cleaning of glasses has been a dangerous, time taking and costly but essential task before introducing self cleaning glass materials, where the glass has a component that will remove the dirt by it self. Other than smart materials, **nanorobots** are the most impressive and demanding research focus of scientists through out the world.

Robots and group work

Before introducing nanorobotics, the background of small-scale robots has to be introduced. In general, robots are machines developed by humans to get a task done; the task may be simple or complex. This may vary from robots used in manufacturing plants to mobile autonomous vehicles used in space exploration.

Basically, a robot consists of several common elements that cannot be eliminated, power source, actuators, sensing devices and computational power (*i.e.* method, processes inputs, and activate outputs). In the past, researchers developed robots that can do variety of tasks with high computational power. These machines are now well established and serving the human kind in various disciplines.

In recent past the interest of researchers in the field of robotics changed from multi-tasking high end robots to

Fig 3 Ant colony doing team work

single tasking, (or can do couple of tasks, but not as previous ones) small in size and low cost robot groups, called as **swarm robotics**. The concept was emerged by studying the biological swarms, such as ants, bees, etc. that are doing enormous teamwork to accomplish a task like nest building, fighting against threats etc.

In the field of robotics the tasks that cannot be done by single robots, such as de-mining, search and rescue missions, are assigned to swarm of robots, with limited computational and sensing power but doing a group work so the limitations can be easily overcome. *Nanorobots* can be specified as a subcategory of swarming robots, buildup of nano-scale components and suppose to do tasks in nano-scale which can be visualized in macro-scale.

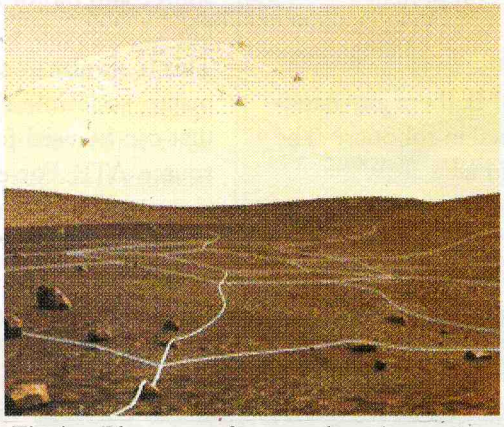


Fig 4 Planet surface exploration using nanorobotics, from artists view (the white lines consists of nanorobots used for data collection)

Why nanorobotics?

The field of nanorobotics becomes one of top research area, due to massive number of possible applications that have high demand in military, medical and space sciences. For example think of a group of robots injected into blood via a normal syringe and moves inside your body's blood vessels, doing a seek and destroy mission on cancer cells without making any side effects to other elements **(smart medicine)**. Even this is like a science fiction; the research on nanorobotics being conducted throughout the world will make it happen in near future.

The possible applications of nanorobotics apart from the medical sciences lies on military and space exploration, for example a group of nanorobots can be deployed for spying purpose into a hostile area, without knowing to the enemies. Or can use them to search and detonate land mines with themselves. The advantages of proposed nanorobots is that they come with the ability to reproduce themselves, like nano factories, so the cost of elements is very low. In the space exploration fields or underwater explorations, the self-replicate nature of the nanorobotics is highly desirable, because one target of the exploration is to spread vast number of nano-scale robots on the target planet surface and get the information from them.

This is much advanced and reliable method compared with sending a single robot to gather information. In current space travels, maintaining a desired health of the astronauts is a much-discussed problem. The nanorobots are to be used for the enhanced health management and protection system for the astronauts, where the preprogrammed nano-scale robots are injected into the body, so that they can protect the astronaut from possible health threats.

Due to the nature of applications the research activities are very competitive and confidential, so outcomes and progress of the research activities are not exposed to the public media.

Biological Flavour?

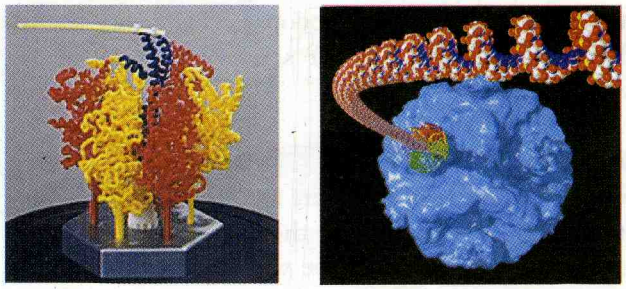
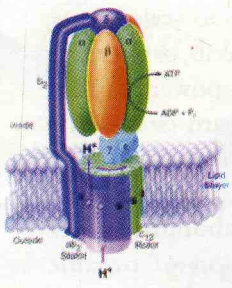


Fig 5 Different models of ATPase motor



Difficulties with nano-scale components

Even though there are many demanding applications for nanorobots the creation of them involves manipulating and working with nano-scale components, which is a very hard as they are invisible to naked eye. Techniques like scanning electron

microscopy (SEM) and atomic force microscopy (AFM) are being employed to establish a visual interface to enable nano-scientists to extend their eyes and hands into the nano-world and also enable new types of exploration and whole new classes of experiments in the biological and physical sciences.

With the facilities to explore the nano-world, scientists faced a great problem in developing nano-scale components for robots, *ie.* the structural elements of the robot, actuators, sensor and processing units have to be developed in nano-scale. Instead of developing artificial components for the parts of the robot, scientists chose the path of using existing nano-scale components.

Machines of mother nature

Existing nano-scale components ... ! Is there any nano-scale components developed to be used in robotics? The answer is YES and they are all around us.....!

Mother Nature has developed a set of molecular machines that have optimized for performance, re-design and tested throughout ages, since the beginning of life on earth. The life and earth relies on those machines, so one should not hesitate to use those machines and components for their designs.

Fig 6 Different views and model of flagella motor

Adding biological flavour to robotics

Is it possible to find molecular components that can do tasks done by classical robot components? YES, scientists have discovered many molecular level 'components' that can easily replace the mechanical components used in classical robotics, thus such systems are defined as bio-nanorobots. Let's discover what are the components and their biological compatibles.

First, every robot (a machine programmed to do a certain task) needs to have a power source. In macro-scale robots; chemo-electric cells, gasoline engines, fuel cells, or electricity from grid for stationary robots, act as power sources. But for nano-scale machine it is very hard (sometimes impossible) to develop a power source like that. In the machines of nature there always being a power source for almost all living cells, known as **mitochondria**, where the power is generated by combustion of organic molecules (glucose) and stored as ATP, the universal energy storage. The same system is suitable for nanorobotics, where the power source supplies chemical energy to the actuators. The process of ATP synthesis is catalyzed by an enzyme called ATP synthase which connects a phosphate group to ADP via high energy bond, and that energy is being released by the catalytic function of ATPase when ever needed.

ATPase in the above mentioned process acts as a molecular motor (as it rotates in the process) and it can be used as a perfect nano-scale compatible for the actuators such as electric motors in the macro-scale robots. Thus ATPase combined with ATP makes a combined power source and motor in molecular level.

This is similar to the electric motors or the actuators of macro scale robots. There are more biological 'devices' that can be used for similar tasks, using the same power source ATP. For example *'the flagella motor'* of bacteria, seems similar to the human scale motor, but use the decomposition of ATP as the power source. There are other types of nano-machines such as DNA actuators, Viral Protein motors do not use ATP as the power source.

The structural-links of macro-scale robots made up of metal, plastic polymer etc. are replaced by *DNA nanotubes* in nano-scale robots and conventional joints are replaced by ***DNA hinges, Molecular Bonds, Synthetic bonds*** *etc.* While transmission elements are proposed to replace by *Beta-sheets.*

What about sensors and processing unit? It is not a big deal to find sensors for the biological machines, because the nature is full of sensors. Think what they are.....?

For the field of robotics, scientists consider few sensors with simple interfaces, like Rhodopsin, Heat Shock Factor, etc. but the candidates for sensors are still under investigation.

Will it succeed?

It is not a truth to say that there are readily available bio-nanorobots developed, but there are many research activities going throughout the world to accomplish the goal of developing first nano-scale working robot. There

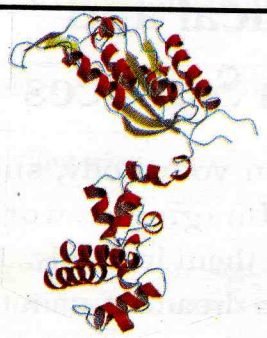
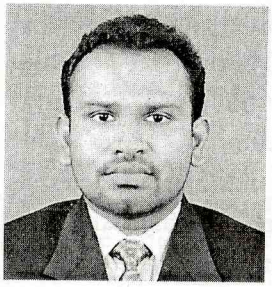


Fig 7 DNA hinge

are still lots of research projects for developing the computational component for the nano-scale machines, and the outcomes are not published yet. Before concluding, it is a must to think about some of the issues that may be raised due to introduction of nano-scale robots. If artificial machines get the abilities such as self replication and self assemblage at nano-scale what would be the out come? Up to now we all, only the living beings had these features. Can a man made machines that go beyond the limitations of nature?



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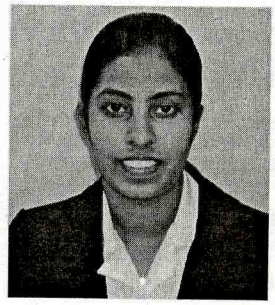

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<Nano-technology>

What is TECHNOLOGY ?

According to many English dictionaries

Technology *is*

"systematic application of knowledge in practical tasks in Industry"

We cannot understand above, if we do not know what is industry!

What is INDUSTRY ?

In most simple terms,

Industry *is*

"Production and Marketing "

Then, TECHNOLOGY is

"application of knowledge in practical tasks in Production and Marketing"

If there is no MARKETING there is no Technology !

Marketing is the critical component of any technology