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NANOROBOTICS: A TUTORIAL

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ABSTRACT

Nanorobotics is an emerging field for designing and building small machines or robots ranging in size from 0.1–10 micrometers. They are microscopic in size; a large number of them may be required to work together to perform microscopic tasks. The field of medicine is expected to receive the largest improvement from Nanorobotics. Nanorobots have attracted a lot of attention from scientists as they can benefit humans in numerous ways. The purpose of this paper is to provide a tutorial on this emerging field.

***Keywords*:** Nano robotics, Nano robots, Nano machines, Nanotechnology.

1. INTRODUCTION

Almost everyone in the electronics industry agrees that there is nowhere the industry can go but down further in scale. Semiconductor chips have already breached the 100- nm feature size, which puts it in the realm of nanotechnology [1]. Nanotechnology (or nanotech) essentially consists of the processing, separating, consolidating, and deforming of materials at an atomic, molecules or cellular level. It is a part of applied science whose theme is to control the matter on atomic or molecular scale. It is becoming increasingly important in fields like engineering, agriculture, microelectronics, and medicine.

Robotics is the theory and application of robots, autonomous electric or mechanical devices. Robots are programmable machines; they can change their physical properties (such as shape, density, conductivity, optical properties, etc.) based on user input or autonomous sensing. When the robot is scaled down to a few billionth of a meter, we have nanotechnology robotics or nanorobotics. Thus, nanorobots are the result of a combination of two technologies: robotics and nanotechnology [2]. Nanorobotics is the nanotechnology technique of building and forming designs of nanorobots. Nanorobots (or nanobots) are controllable machines that are composed of nano scale components. They are capable of performing tasks such as actuating, sensing, signaling, and information processing at the nanoscale. Because the development takes place on an atomic scale, these nanobots can pull apart any kind of material (soil, water, air, etc.) atom by atom and construct just about anything.

2. OVERVIEW OF NANOTECHNOLOGY

Techniques are now available which make it possible to manipulate materials on the atomic or molecular scale to produce objects which are no more than a few nanometres in diameter. The processes used to make and manipulate such materials are known as *nanotechnology*, the materials or objects themselves are called *nanomaterials*, and the study and discovery of these materials is known as *nanoscience*.

Richard Feymann, the Nobel Prize-winning physicist, introduced the world to nanotechnology in 1959. Nanotechnology involves the manipulation of atoms and molecules at the nanoscale so that materials have new unique properties. It deals with materials, structures, and systems whose components exhibit novel physical, chemical, and biological properties due to their nanoscale sizes. Nanotechnology is a multi-disciplinary field that includes biology, chemistry, physics, material science, and engineering. It is the science of small things—at the atomic level or nanoscale level [3].

Nanotechnology seems to be one of the most dominant technologies of the century. It has numerous applications in everyday life, ranging from consumer goods to medicine to improving the environment. Nanotechnology involves imaging, measuring, modeling, and manipulating matter at the nano scale. It covers a wide variety of disciplines like physics, chemistry, biology, biotechnology, information technology, engineering, and their potential applications. Nanotechnology has a vast range of applications, such as in nanomedicine, nanoelectronics, biomaterials energy production, and consumer products. It is revolutionizing many industry sectors: information technology, homeland security, medicine, transportation, energy, food safety, and environmental science. Nanoparticles are used increasingly in catalysis to boost chemical reactions, especially petroleum refining and automotive catalytic converters.

The possibilities with nanotechnology are limitless. Nanotechnology will likely revolutionize sensor capabilities. With nanotechnology, it seems like anything is possible.

3. CONCEPT OF NANOROBOTICS

Nanorobotics is a major field of nanotechnology. It is the technology of producing robots at the nanoscale. Nanorobots (or nanobots) are like any other self-assembling robotic device such as those used for car assembly. The main difference lies in the fact that nanobots use the atomic building blocks of matter to assemble their products [4]. Nanorobots are invisible to the naked eye, which makes them hard to handle. They are basically nanoelectromechanical devices (NEMS) designed to perform a specific task with precision at nanoscale dimensions. They may be synthetic or biological. They are often fabricated in desktop nanofactories specially designed for this purpose. Each nanorobot has power supply, navigation facility, communication, locomotion, and sensors. The major element used nanorobots is carbon because of its inertness and strength. Other elements include hydrogen, oxygen, nitrogen, sulphur, and silicon which are used on nanoscale. A typical nanorobot is shown in Figure 1 [5].

Nanorobotics is a field that requires the collaborative efforts of physicists, chemists, biologists, computer scientists, and engineers. It is a convergence of technologies as showin in Figure 2 [6]. The ideal characteristics of nanorobots include [7].

- Nanorobots must have size in between 0.5 to 3 microns large with 1 - 100 nm parts.
- It will prevent itself from being attacked by the immune system by having a passive, diamond exterior.
- It will communicate with the doctor by encoding messages to acoustic signals at carrier wave frequencies of 1 - 100 MHz.
- It might produce multiple copies of it to replace worn-out units, a process called self-replication.
- It should possess swarm intelligence – decentralization and distributive intelligence.
- It should possess nano information processing and programmability – for programming and controlling nanobots.

Nanorobots come in all shapes and sizes. They are classified according to their application. There are several types of nanorobots including the following [8].

- *Smallest engine ever created:* A group of physicists from the University of Mainz in Germany recently built the smallest engine ever created from just a single atom.
- *3D-motion nanomachines from DNA:* Mechanical engineers at Ohio State University have designed and constructed complex nanoscale mechanical parts using 'DNA origami.'
- *Nanoswimmers:* ETH Zurich and Technion researchers have developed the nanoswimmers which can be magnetically controlled to swim through the bloodstream to target cancer cells.
- *Ant-like nanoengine:* University of Cambridge researchers have developed a tiny nano-engine which can lead to nanorobots small enough to enter living cells to fight disease.
- *Sperm-inspired microrobots:* A team of researchers at the University of Twente (Netherlands) and German University in Cairo (Egypt) has developed sperm-inspired microrobots.
- *Bacteria-powered robots:* Drexel University engineers have developed a method for using electric fields to help microscopic bacteria-powered robots detect obstacles in their environment and navigate around them.
- *Nanorockets:* Several groups of researchers have recently constructed a high-speed, remote-controlled nanoscale version of a rocket.
- *Pharmacyte:* This is a medical nanorobot that is controlled using mechanical systems for sorting pumps.

These are not the only nanorobot prototypes the researchers have developed. For several years, they have been creating different types of nanorobots.

4. MEDICAL APPLICATIONS

A major benefit of using nanoscale for medical technologies is that smaller devices are less invasive and can possibly be implanted inside human body. Nanorobots can travel inside the human body and navigate as blood-borne devices. They can detect chemicals in the body and monitor biomechanical characteristics. Due to their tiny size, nanomedicines can readily target difficult-to-reach sites with improved solubility and reduced adverse effects. The potential near-endless applications of nanorobotics in medicine include cancer treatments, treatment of diabetes, heart-attack prevention, bone reconstruction, imaging contrast agents, drug delivery, psychiatric diseases, Alzheimer's disease, kidney stones removal, biomedical instrumentation, surgery, hematology, pharmacokinetics, monitoring of diabetes, and some other treatments that can save human lives.

- *Nanomedicine:* The first useful applications of nanomachines may be in nanomedicine. Nanomedicine is a branch of medicine that involves the development and application of materials and technologies with nanometer length scales. It is an interdisciplinary research field that results from the application of nanotechnology to medicine. It is focused on medical intervention at the molecular scale. An advanced application of nanomedicine involves the use of nanorobots and nanodevices as miniature surgeons [9]. Nanomedicine's nanorobots are so tiny that they can easily traverse the human body. Nanorobots can be an innovative, supportive, and optimistic machine technology for patients in the treatment and diagnosis of life threatening diseases.

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- *Dentistry:* Nanorobotics will become an important part of future dental and periodontal health. Due to the growing interest in the dental applications of nanotechnology, a new field called "nanodentistry" is emerging. Dental nanorobots might use some specific tools to penetrate human tissue with navigational precision and manipulate their surroundings in real time. They can identify and destroy pathogenic bacteria that exist in the plaque and elsewhere. Orthodontic robots allow painless tooth uprighting, rotating, vertical repositioning, and repair [10]. Nanodental techniques involve applying several tissue engineering procedures for major tooth repair.

- *Drug Delivery:* Nanotechnology provides a wide range of new technologies for developing customized means to optimize the delivery of pharmaceutical drugs. When the nanoparticle encounters a cancer cell, it releases the drug into the cancer cell. This targeted means of drug delivery has great potential for treating cancer patients while avoiding negative effects [11]. Nanorobots can offer a number of advantages over the current drug delivery methods. These include more bioavailability, targeted therapy, fewer surgeon mistakes, reach remote areas in human anatomy, and non-invasive techniques.

- *Cancer Treatment:* Nanorobots help identify and destroy cancer cells more accurately and effectively. Nanorobots with chemical biosensor are used for detecting the tumors cells development inside the patient's body in early stage of cancer. The DNA nanorobots do so by seeking out and injecting cancerous tumors with drugs that can cut off their blood supply, leading to their death. The current method of using chemotherapy to destroy every cell is barbaric in comparison [12].

- *Surgery:* Surgical nanorobots can be introduced into the body through the vascular system and perform various functions such as diagnosing, detection of pathology, correcting lesions by nanomanipulation, etc. A surgical nanorobot, programmed or guided by a human surgeon, could act as a semi-autonomous surgeon inside the human body [13].

- *Medical Imaging:* Creating nanoparticles that gather in certain tissues and then scanning the body with a magnetic resonance imaging (MRI) could help highlight problems such as diabetes. Imaging tools commonly used in nanorobotics are mainly electron and scanning probe microscopes.

5. OTHER APPLICATIONS

Nanorobot is basically a controllable machine at the nanometer or molecular scale. Nanorobots may be regarded as any structure capable of actuation, sensing, signaling, information processing, intelligence, and swarm behavior at nano scale. Beside medicine, nanorobotics have applications in manufacturing, space technology, power system, environment, materials science, detection of toxic chemicals, data storage, nanophotonics, nanoassembly, machines, circuits, nanowaveguides, and processing. They are candidates for industrial applications, the military, and space technology.

- *Space Technology:* Telerobotic systems for operating robots in hazardous environments, outer space or deep seas have been of current interest. Because of their small size, nanorobots are easy to use in space applications and can be easily propelled; it can reach required orbits easily and in less time. Nanorobots can lower the cost of reaching orbit and traveling in space. Space nanorobots can be used in carrying out construction projects in hostile environments [14]. Nanorobots can be used to actively repair damaged suit materials while an astronaut is in the field.

- *Manufacturing*: Nanotechnology makes it possible to achieve several benefits when you manufacture materials. Nanorobotic manufacturing is based on tailored nanoelectronics This method for manufacturing on nanotechnology scale is in use in the electronics industry since 2008. So, practical nanorobots should be integrated as nanoelectronics devices. Nanobhis is a feasible way of manufacturing Nano devices. 3D printing allows a three-dimensional structure to be constructed through the various processes of additive manufacturing. Nanoscale 3D printing involves the same process at a much smaller scale [14].

- *Nanoassembly:* Assembly of components into more complex structures is a primary goal of robotics at all scales. It involves positioning the required components and joining them with other subassemblies in a hierarchical manner. Nanomanipulation is a promising approach for nanoassembly.

- *Nano Power Sources:* Potential nano robot power source is a modified microbial fuel cell. Nanobots can derive energy directly by utilizing blood glucose and oxygen. The nanorobot uses the glucose molecules present in the human body as the power source.

6. BENEFITS

Nanorobots are regarded to be among the most powerful tools ever created by man.
The benefits/advantages of nanorobots include [7]:

- Low price to produce and easy to manipulate.
- Operates autonomously, independent of outside control.

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- Will be used to maintain and protect the human body against pathogens.
- Use of nanorobot drug delivery systems with increased bioavailability.
- Targeted therapy such as only malignant cells treated.
- Rapid treatment and elimination of diseases.
- Nanorobots are durable and can remain operational for a very long time.
- Reach remote areas in human anatomy not operable at the surgeon's operating table.
- Drug molecules are carried by nanorobots and released where needed.
- Non-invasive technique with no side effect.
- To replace worn out units, nanorobots might also produce a replica of themselves known as self-replication**.**
- Drug inactive in areas where therapy not needed minimizing undesired side effects.
- Small size- The upper limit of the size of nanorobot is 3 micron so that it can easily flow in the body without blocking the capillary flow.
- Manufacturing by batch processing reduces the cost even if the initial cost of development is high.
- Less post treatment care - As it is minimally invasive technique, therefore less post treatment care is required.

7. CHALLENGES

Discussions on nanorobots remain at the level of unbuildable generality and do not yet approach the level of detailed engineering. The challenges faced in realizing nanorobots that can rival their biological counterparts are manifold. The challenges/disadvantages include the following [15,16]:

- The initial design cost is very high.
- The design of the nanorobot is a very complicated one.
- The size-related challenge is the ability to measure, manipulate, and assemble matter with features on the nano scale.
- It is also difficult to make and navigate to the target organs.
- Conflicting opinions remain regarding the use of nanorobots *in vivo*.
- There is the challenge of precise actuation.
- Electrical systems can create stray fields which may activate bioelectric-based molecular recognition systems in biology.
- Electrical nanorobots are susceptible to electrical interference from external sources such as RF and stray fields from other *in vivo* electrical devices.
- Nanorobots can cause a brutal risk in the field of terrorism. The terrorism and anti-groups can make use of nanorobots as a new form of torturing the communities as nanotechnology also has the capability of destructing the human body at the molecular level.
- Privacy is the other potential risk involved with nanorobots. As nanorobots deals with the designing of compact and minute devices, there are chances for more.
- Hard to interface, customize, and design.

These challenges prevent robots from being reduced to a nanoscale with current technology. Thus, the field of nanorobotics is still in research and development stage.

8. CONCLUSION

Nanorobotics is the emerging application for developing machines which are of nanoscale. It involves the study of robotic devices that possess functional features or components with nanoscale size. Engineers and scientists around the world are working to design nanorobots that will be used to treat everything from manufacturing to cancer. Although nanorobotics faces many significant challenges in bringing its promises to fruition, it has strong potential to revolutionize medicine in the future. We are possible many years away from seeing the first medical nanorobots.

Global nanorobotics market was valued at US$ 3.7 Bn in 2017 and is expected to reach US$ 9.2Bn by 2026. This is illustrated in Figure 3 [17]. More information about cluster computing can be found in books in [18-20].

REFERENCES

[1] S. A. Edwards, *The Nanotech Pioneers*. Wiley-VCH Verlag, Chapter 7, 2006. pp. 107-124.
[2] P. R. Bhore, "A survey on nanorobotics technology," *International Journal of Computer Science & Engineering Technology*, vol. 7, no. 9, Sept. 2016, pp. 415-422.
[3] M. N O. Sadiku, M. Tembely, and S.M. Musa," Nanotechnology: An introduction," *International Journal of Software and Hardware Research in Engineering*, vol. 4, no. 5, May. 2016, pp. 40-44.
[4] D. J. Wilson, "Nanorobotic devices," October 2018, https://www.news-medical.net/health/Nanorobotic-Devices.aspx.
[5] K. M. Poornima et al., "Bio-nanorobotics: The milestone of nanotechnology and medicine," *International Journal of Advanced Research in Computer Science*, vol. 5, no. 6, July-August 2014, pp. 306-309.

DOI: 10.31695/IJASRE.2019.33427

[6] L. Dong and B. J. Nelson, "Robotics in the small, Part II: Nanorobotics," *IEEE Robotics & Automation Magazine*, September 2007, pp. 111-121.
[7] K. S. Sarath, P. N. Beena, and A. Elessy, "Nanorobots a future device for diagnosis and treatment," *Journal Pharm Pharmaceutics*, vol. 5, no. 1, 2018, pp. 44-49.
[8] "Different yypes of nanorobots and applications," Unknown Source.
[9] M. N. O. Sadiku, T. J. Ashaolu, and S. M. Musa, "Nanomedicine: A primer," *International Journal of Trend in Research and Development*, vol. 6, no. 1, Jan.-Feb. 2019, pp. 267-269.
[10] N. J. Shetty, P. Swati, and K. David, "Nanorobots: Future in dentistry," *The Saudi Dental Journal*, vol. 25, no. 2, April 2013, pp. 49–52.
[11] "Nanorobotics," *Wikipedia*, the free encyclopedia, https://en.wikipedia.org/wiki/Nanorobotics
[12] S. Buhr, "New DNA nanorobots successfully target and kill off cancerous tumors," https://techcrunch.com/2018/02/12/new-dna-nanorobots-successfully-targeted-and-killed-off-cancerous-tumors/
[13] M. Kharwade, M. Nijhawan, and S. Modani, "Nanorobots: A future medical device in diagnosis and treatment," *Research Journal of Pharmaceutical, Biological and Chemical Sciences*, vol. 4, no.2, April-June 2013, pp. 1299-1307.
[14] "Nanotechnology and nanorobotics for space applications," July 2013, https://www.slideshare.net/gvrteja/nanotechnology-and-nanorobotics-for-space-applications
[15] P. Khulbe, "Nanorobots: A Review," *International Journal of Pharmaceutical Sciences and Research*, vol..5, no. 6, 2014, pp. 2164-2173.
[16] R. Kumar et al., "Applications of nanorobotics, "*International Journal of Scientific Research Engineering & Technology*, vol. 3, no. 8, November 2014, pp. 1131-1137.
[17] "Global nanorobotics market, industry analysis and forecast (2018-2026) –By type, application, and region," https://www.maximizemarketresearch.com/market-report/global-nanorobotics-market/30888/
[18] C. Mavroidis and A. Ferreira (eds.), *Nanorobotics: Current Approaches and Techniques*. Springer, 2013.
[19] K. D. Sattler (ed.), *Handbook of Nanophysics: Nanomedicine and Nanorobotics*. Boca Raton, FL: CRC Press, 2010.
[20] T. Jadczyk et al., *Innovative Diagnostics and Treatment: Nanorobotics and Stem Cells*. Springer, 2017.

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Figure 1 A typical nanorobot [5].

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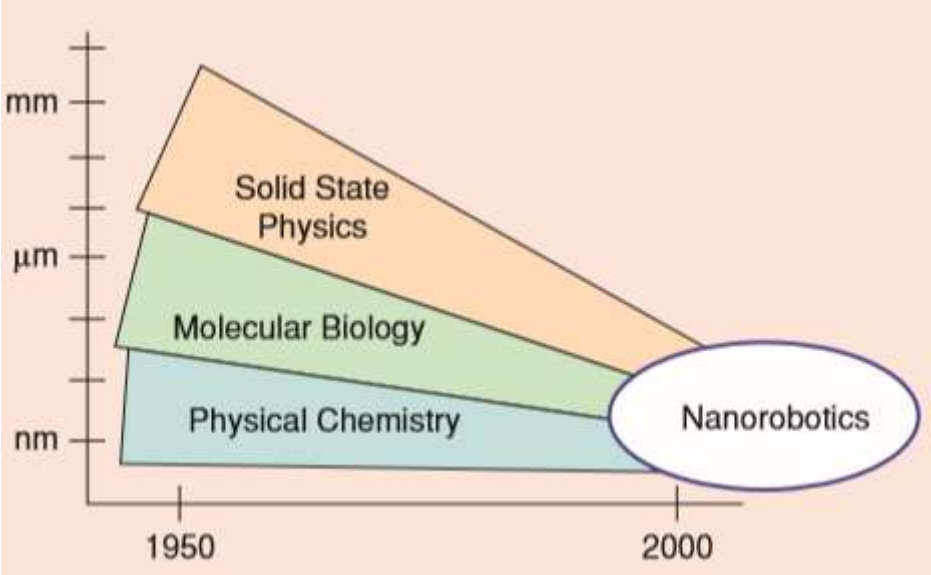

Figure 2 Nanorobotics is a convergence of technologies [6].

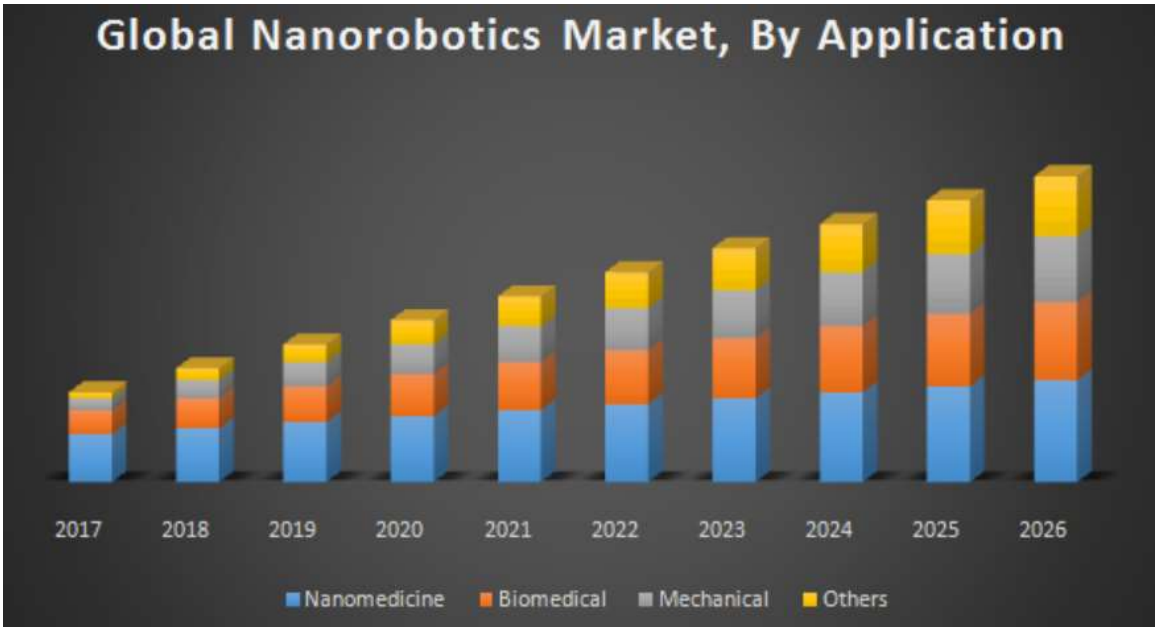

Figure 3 Global Nanorobotics Market [17].

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