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Nan robots: Survey on Recent Developments in Medical Application

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Abstract- **This paper provides a technical survey on recent developments of nanorobots in medical applications. The recent advancement of nanotechnology leads to nanorobots, which are effectively used as nanomedicine to perform treatments even at the cellular level. Much research work has been carried out based on the nanorobots such as diagnosing, treating, preventing disease, some traumatic injury, of relieving pain and improving human health using some tools and molecular knowledge of human body. This paper covers the architecture of nanorobots using sensors for medical target identification and drug delivery. The focus of this paper is on the nanorobots design, path planning .detection and its control movements inside human body.**

Keywords: **architecture, drug delivery, nanorobots, obstacle avoidance, path planning, target detection.**

I. INTRODUCTION

Nanotechnology based nanorobots has framed science with engineering activities at the cellular level. Nano-sized nanorobots can investigate any biological environment (cell culture or human body) at the microscopic level. This paper deals with the nanorobots architecture, path planning, detection and drug delivery in medical field. The nanotechnology has made tremendous improvement from the past so many years; the paper deals with a survey of past and recent developments of nanorobots in medical applications. The medical conditions such as cancer and thrombi follow some temporal pattern by employing some artificial intelligence based methods to find the affected region in the body. Recently, nanorobots has been tried to function as a next generation pills which is a nano-shaped capsule, carrying the required therapeutic material for the targeted region. These capsules are considered to have their own decision making ability for avoiding obstacles such as immune system attack and reaching the particular region based on path planning algorithm .The human body is a complex system with 3D structure, thus modelling of such system at cellular level also requires 3D mapping of each cell.

There has been a lot of research work being carried out based on nanotechnology for solving medical problems. Freitas [1], author of nanomedicine gives us an example of one type of medical nanorobot that would act as a RBC.It consists of carbon atoms in diamond pattern which includes inter – nanorobot communication, biocompatibility issues, locations and applications. However, his work does not throw much light on nanorobot architecture which depends a lot on its compatibility with the region in which it performs its investigation. So, there is a requirement which helps to find all the affected regions in our body [2] especially at the cellular level. According to Sitti [3], there is a future challenge to find methods for interacting with these nanorobots inside the body. Cavalcanti [4] has proposed hardware architecture for nanorobot application in cerebral aneurysm. He also discussed about the different parameters required for architecture prototyping , its control activation as well as the manufacturing technologies at molecular machine prototype for medicine and provides better and accurate results as compared with the other techniques .Hla[5] discussed the collective movements in nanorobots based on particle swarm optimization for obstacle avoidance continuing on a trajectory at 2 dimention.However, his work does not gives much detail about the self organisation process. Gayle [6] discussed about the path planning algorithm for deformable robots for liver chemoembolization using catheter (robot) but there are some drawbacks such as it is capable to work only in small environment only, also it requires pre operatively path planning where obstacles are considered to be static .Cavalcanti [7] has provided an innovative approach for medical target identification to improve diagnosis and provides a new therapeutic procedure based on 3D prototyping. This work can further be developed into more VLSI (very large scale integration) features functionality and exceptional performance under nanoscale sizes. Paul [8] has provided a fuzzy logic based approach to identify metastatic tumours by DNA nanorobots which can further be used in some better approach in 3Dimension environment. Hogg [9] discusses about the acoustic signals based on distance range. However, it does not include other parameters apart from velocity and pressure which also generates sound inside our body.Cavalcanti [10] along with his co authors proposes the use of CMOS based chips for manufacturing nanorobots. However, it does not provide the algorithm required to follow and its measures both in quality and quantity in 3Dimension biological system.

This paper proposes a framework that has taken into account the concerns in the above scholarly papers. We know that magnetic resonance imaging (MRI) and positron emitting tomography (PET) can scan images of the body at the tissue level. However; in this paper we can scan the images of the body at cellular level.

II. METHODOLOGY: FROM SCIENCE FICTION TO REALITY

Following a brief introduction, this paper describes a number of recently reported nanorobots development activities in medical field. It then briefly considers the emerging fields of nanorobotics. In the first section of this part we are going to discuss about the recent developments in nanorobot architecture. The next section deals with a brief introduction of nanorobot path planning which includes both control movement and obstacle avoidance performed by the nanorobots inside the body. The nanorobot target detection and drug delivery is being discussed in the last section of this part followed by the emerging fields of nanorobots in medical applications.

i) Nanorobot Architecture

The integrated hardware architecture has been discussed in this section. The integrated system, smart biosensors and programmable nanodevices are all set to take this field to a new height. Most recently, use of RFID [7] (radio frequency identification) and mobile phones has been explored for data collection and transmission inside the body. The nanorobots are designed in such a fashion so as o prevent it from the immune attacks [7].Recently, many chemical assembled electronic nanotechnology has been adopted as an alternative to the metal oxide semiconductors (CMOS) [4].Emphasis are given to frame such nanorobots which are based on ASIC (application specific integrated circuit) for common medical applications. The nanorobot architecture depends upon the environment with which these devices are going to perform its function. For biomedical application, temperature, concentration of chemicals in blood, electromagnetic signatures [7], acoustic signals [9], velocity [6] of nanorobot and fluid are some of the parameters which are required to be considered for the nanorobot architecture.

Different architecture design such as CMOS,VHDL(very high design language), SOI(silicon-on-chip insulator) based technology has been adopted for different medical problem diagnosis.Cavalcanti [4] has adopted chemical sensor based nanorobots architecture programmed with CMOS technology to detect some neurodegenerative diseases like Alzheimer and Parkinson based on pattern signals. Preferences are now been given to the biological based components which does not gives any side effects. Recently, acoustic signals has been used as sensors for communication and detection purpose with low energy consumption as compared to light based sensors for communication approaches up to 10^4 bits/s between nano-sized robots [9].which do not damages even the nearby tissues for therapeutic use.

ii) Nanorobot: Path Planning

The nanorobot navigation in a liquid environment is the main consideration during the path planning inside the body. It is important that the device is having a smooth trajectory path while navigating in the blood environment and at the same time does not cause any damage to the other cells.Sitti [3] proposes a swimming microrobots which are propelled by artificial flagella to destroy the blood clot that threatens the patient's life. These tiny shaped microrobots access small space inside human body that can currently be reached only by using invasive methods. Earlier, nanorobots were suppose to work in a small environment , Gayle [6] proposes an algorithm for short distance path travel based on 2.5 D overlap and Murkowski sum to detect tumour in liver chemoembolization. Now a day's self trajectory plan for path detection by the nanorobots are being practised shaped microrobots access small space inside human body that can currently be reached only by using invasive methods. Earlier, nanorobots were suppose to work in a small environment , Gayle [6] proposes an algorithm for short distance path travel based on 2.5 D overlap and Murkowski sum to detect tumour in liver chemoembolization. Now a day's self trajectory plan for path detection by the nanorobots are being practised

a) Control Movement in Nanorobots

Cavalcanti [4] provided some new features in the nanorobots which are effectively used as nanomedicine. The pill shaped nanorobots are employed with a self trajectory plan where theses nanorobots are made decision makers inside the human body. Three behavioral control techniques have been considered to control the nanorobots' motions. First approach used nanorobots' small Brownian motions [7] to find the target by random search. In second approach, nanorobot monitors for chemical concentration intensity [4] for E-cadherin signals. After detecting the signal, the nanorobot estimates the concentration gradient and moves toward higher concentrations until it reaches the target. In third approach, nanorobots at the target release another chemical, which others use as an additional guiding signal to find the target [4]. In this paper, the particle swarm optimization algorithm (PSO) is proposed as an appropriate control algorithm to control nanorobots' mobility within a human body.

b) Obstacle Avoidance by Nanorobots

One of the major aspects in the movement control of a nanorobot is obstacles avoidance. Every nanorobot placed inside the human body will encounter immune system as obstacles during flowing within a human body. Thus nanorobot must use strategy for avoiding and escaping from such immune system. The nanorobot equips with sensors to detect obstacles and identifies when it has encountered. Earlier, nanorobots work in small environment so as to avoid less number of obstacles. Now day's nanorobots are able to work at complex environment with increased number of non static obstacles. So self trajectory plan has been adopted to avoid such obstacles. Different approach has been adopted based on the position of nanorobots.Cavalcanti [4] [6] has discussed about the obstacle avoidance algorithm based on the local and global path of the position between the nanorobot and the obstacle Fig.1. He has consider obstacle shape as circular for convenience

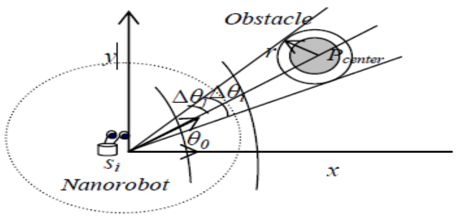

Fig.1Obstacle in Polar Coordination

He considered Polar Coordinate system, determined by an angle and a distance used to find out the trajectory for obstacle avoidance. Each obstacle can be represented in polar coordination by following equation:

$$r^2\text{-}2rr_i\cos(\theta\text{-}\ \theta_i)\ +r_i^2\text{-}r^2=0 \quad (1)$$

In which, *r* is radium of obstacle and (*ri, θi*) is the center of the obstacle. Suppose a nanorobot moves at a certain distance (*xi,yi*) and both obstacle and nanorobot move with the same fluid velocity *vf* (*vfxi,vfyi*), the new position of obstacle (*xj,yj*) within time Δ*t* can be calculated as follows:

$$x_j=x_i+v_fx_i*\Delta t;\quad y_j=y_i+v_fy_i*\Delta t \quad (2)$$

The distance Δ*d* between a nanorobot and the center of the obstacle, *Pcenter* within time Δ*t* can be calculated by using the following equation.

$$\Delta\mathbf{d} = \sqrt{(\mathbf{x_j} + \mathbf{v_f x_j} * \Delta\mathbf{t} - \mathbf{x_i} + \mathbf{v_f x_i} * \Delta\mathbf{t})^2 + (\mathbf{y} + \mathbf{v_f y} * \Delta\mathbf{t} - \mathbf{y_i} + \mathbf{v_f y_i} * \Delta\mathbf{t})^2}$$

(3)

Based on the collision time, nanorobot can predict the obstacle's future position and adjust the movement trajectory. He also discusses about the use of chemical sensors so as to avoid the obstacle based on the signal pattern.

c) Target Detection and Drug Delivery by nanorobots

Many advance research has been adopted to detect the targeted region for the diagnosis purpose. Based on past experiences researchers have tried to develop some method to work only on the affected region which are considered to be damaged cells leaving the healthy cells untouched[4] [6] [8] [10] Angioplasty surgery has now been considered to be out dated where nearby cells also get damaged and chances of recurrences are also developed sometimes. Recently, NanoActuator and Nanosensors for Medical Application (NANOMA) aimed to develop a microrobotic system for the propulsion and navigation of ferromagnetic microcapsule in cardiovascular system through induction on magnetic gradients. There are many changes inside our body which help the nanorobots to detect the target and supply the drug at a specific location. Researchers has now adopted many advanced techniques to detect the target which are based on the biological chemical sensors developed inside our body .Lock and Key approach has now been tried to be implemented so as to supply the specific drug to the specific cells only. The nanorobots carries specific drug (lock) which supplies to the specific receptor cell (Key) so as to detect the target.

iii) Emerging Fields of Nanorobot in Medical Application

Nanotechnology involves manipulating properties and structures at the nanoscale, often involving dimensions that are just tiny fractions of the width of a human hair. One area of nanotechnology application that holds the promise of providing great benefits for society in the future is in the realm of medicine. Nanotechnology is already being used as the basis for new, more effective drug delivery systems and is in early stage development as scaffolding in nerve regeneration research. Nanotechnology is already moving from being used in passive structures to active structures, through more targeted drug therapies or "smart drugs". In the future, nanotechnology will also aid in the formation of molecular systems that may be strikingly similar to living systems. These molecular structures could be the basis for the regeneration or replacement of body parts that are currently lost to infection, accident, or disease. Current and future applications of nanotechnology [18] in various fields of medicine have been categorized into two parts: a. Current Medical Applications b. Commercialization Timelines.

- Current medical application are employed by researchers involved in drug discovery, physicians in need of better imaging techniques, and as prescriptions to treat particular kinds of illness such as cancer, bone replacement, cholesterol, drug development test, hormone therapy.
- Commercialization timelines illustrate estimated commercialization time frames for a select set of nanotechnology drugs, delivery systems, diagnostic tests and devices that are currently being developed—from applications that are in early stage development to applications that are already in latter stages of clinical trials. The number of years allocated to each phase of the development process (early stage development, preclinical testing, phase I clinical testing, phase IIa clinical testing, phase IIb clinical testing, phase III clinical testing, and FDA review/process) is based on the report "Phases of Product Development," published by Dale E. Wierenga, Ph.D. and C. Robert Eaton. According to data provided by Nanobiotech News' 2006 Nanomedicine, Device & Diagnostics Report. As shown in the timelines, there are 77 drugs, delivery systems, diagnostic tests and devices related to cancer and 56 related to drug delivery in general. In both cases, it is evident that a vast majority of items fall within the early stage development and preclinical testing phases. These applications are just a fraction of the actual number of nanotechnology products currently in the development pipeline; however, this trend is one that is seen for products in most branches of nanomedicine.

III. ROADMAP TOWARDS NANOROBOTICS

It is required to make progress in each phase of the development of the nanorobot. The nanorobots are now successfully designed and embedded with advanced techniques. Multiple shape and size has been employed depending upon the environment it has to perform the task. Researchers are trying to develop such nano shaped nanorobots which can easily navigate and perform specific function. Earlier, pre defined small environments were adopted by the researchers to perform the task. Later, these nanorobots started working in a complex environment with increased number of obstacles during the path planning. Researchers have been trying to develop such nanorobots which are self decisive in path making and target detection. Many advanced progresses has been made in this field based on 1 dimensional and 2 dimensional environments such as DNA nanorobots to detect cancer and tumor cells inside our body .Recently, deformable robots based on 2.5 overlap test helps to detect liver tumours.Reserachers are now working on 3D environment to detect cancer cells inside our body. There need to make a long route progress in this field.

IV. CONCLUSION

The nanorobots are a topic of advanced research work and many different technological approaches are under study. Nanorobots are at a far earlier stage of development in medical field and it can be extended to study the adaptation techniques inside our body using nanorobots.MRI, PET, CT (computer Tomography) can find the affected regions at tissue level. However, we can find the affected regions at the cellular level using these tiny particles. This paper provides a timely survey of recent developments of nanorobots activities in medical applications.

V. FUTURE SCOPE

It would be interesting to study these nanorobots in 4 dimensional biological systems. A nanorobot has to be small and agile enough to navigate through the human circulatory system, even at complex networks of veins and arteries. Nanorobot isn't meant to stay inside the patient, however it is also required to make its way out of the body .A fully functional nanorobot having control at nanoscale can be a future scope in this field along with getting smaller and smaller in size with efficiency.

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