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BIOLOGICAL NANOROBOT ARCHITECTURE FOR MEDICAL TARGET IDENTIFICATION

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ABSTRACT

This work has an innovative approach for the development of biological nanorobots with sensors for medicine. The biological nanorobots operate in a virtual environment based on random, thermal and chemical control techniques. The biological nanorobot architecture model has biological nano bioelectronics as the basis for manufacturing integrated system devices with embedded biological nano biosensors and actuators, which facilitates its application for medical target identification and drug delivery. The biological nanorobot interaction with the described workspace shows how these biological nanorobots detect the target area and supply the drug. Therefore, our work addresses the control and the architecture design for developing practical molecular machines. Advances in nanotechnology are enabling manufacturing nanosensors and actuators through nano bioelectronics and biologically inspired devices. Analysis of integrated system modeling is one important aspect for supporting nanotechnology in the fast development towards one of the most challenging new fields of science: molecular machines. The use of 3D simulation can provide interactive tools for addressing nanorobot choices on sensing, hardware architecture design, manufacturing approaches, and control methodology investigation.

INTRODUCTION: Nanoscale science has become a challenging area in building a biomolecular scale device. Nano engineering advances programmable and controllable nanoscale robot called nanorobot which performs specific task with precision at nanoscale dimension can work inside human body.

In near future, nanoscale technology will allow the production and deployment of nanorobots for investigating within human body providing information about the target environment. Though nanorobots have not yet been able to produce, theoretical studies identify their possibility sort of capabilities in nanomedicines. Chemical recognition is used to find out the target within human body.

The target has surface chemicals that allow the nanorobots to detect and recognize it. By measuring changes in volume, concentration, displacement and velocity, pressure, or temperature of cells in a body, nanorobots may be able to distinguish between and recognize certain cells.

Movement of is carried out in self organized way by applying Particle Swarm Optimization algorithm. Along with the self organized behavior, obstacle avoidance is also considered to get the complete control strategy during movement trajectory. Obstacle should be avoided intelligently when a nanorobot has been placed within human body.

In our work, the focus of interaction and sensing with nanorobot is addressed giving details on the workspace chemical and thermal signals dispersion through a 3D environment as a testbed for prototyping and analyzing. There have been some proposed solutions for obstacle avoidance and target detection with Swarm Intelligence. Multiple robots in 3D environment move by avoiding obstacles and provide path to the target using swarm intelligence technique where they are suppose to dilute the blood clot. Biological nanorobots do not have any side effects and chances of recurrences are also avoided. . Since the scale of operation is very small, the results are also very accurate.

Literature Review: DNA nanorobot design and methodology are being discussed for the identification of metastatic tumor cells and DNA nanorobot [1] controlling techniques for its movement in dynamic environment by using fuzzy logic rules which identifies tumor cells. 3D simulation based on clinical data addresses to integrate communication with nanorobots. Focused ultrasound (FUS) with micro bubbles has been discovered to locally increase the permeability [11] of blood–brain barrier (BBB). It indicates the location of hyper echoic spots and with hemorrhage areas. Biosensors are used to incorporate living components, including tissues or cells which are electrically excitable or are capable of differentiating into electrically excitable cells, and which can be used to monitor the presence or level of a molecule in a physiological fluid [10].

Objective: Considering the properties of nanorobots to navigate as blood borne devices, they can help important treatment processes of complex diseases in early diagnosis and smart drug delivery. Any approach to control dynamic system needs to use some knowledge or model of the system to be controlled. In case of nanorobots, this system consists of the nanorobots plus the environment in which it operates.

The aim of the investigation is to present a possible way application in the field navigation of nanorobots in structured and unstructured obstacles especially in a changing environment. The wide applicability in navigation is mainly based on Swam Intelligence Principle which is achieved through if- then rules.

Nanorobots as drug carriers for timely dosage regimens allows maintaining the chemical compounds for a longer time as necessary into the bloodstream circulation, providing predicted pharmacokinetic parameters for chemotherapy in blood clot diffusion. Nanorobots with chemical nanobiosensors can be programmed to detect different levels of *E-cadherin* and beta-catenin[2-4] as medical targets helping target identification and drug delivery.

Biological nanorobots using biological chemical sensors as embedded nanoelectronics can be programmed to detect different levels of nitric oxide synthase (NOS) pattern signals [7] as medical targets in early stages. A protein called fibrinogen, starts increasing which also shows a symptoms of blood clot in brain. This information guide possible immunotherapy treatments, with more efficient neurotransmitters [8, 6] deliveries, like indoleamines- nitrogen containing chemical molecules used by brain to transmit signals with better medical administration.

MATERIALS AND METHODS: The main parameters used for the medical nanorobot architecture and its control activation, as well as the required technology and current development that can lead to manufacturing hardware for molecular machines. Structure of nanorobot is shown in **Fig. 1**.

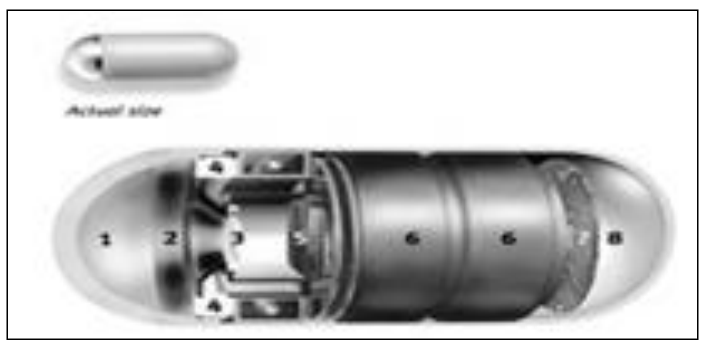

FIG: 1 STRUCTURE OF BIOLOGICAL NANOROBOT

Manufacturing technology: The architecture for a biological nanorobot must include the necessary devices for monitoring the most important aspects of its operational workspace: the human body. To reach this aim, data processing, energy supply, and data transmission capabilities should be addressed through embedded integrated circuits, using advances in technologies derived from nanotechnology and VLSI design.

A large set of different chemical and biological sensors has been achieved with distinct sequences of peptides through combinatorial chemistry for selective detection of various medical targets. The use of VHDL (very high speed integrated circuit hardware description language) has become the most common methodology utilized in the integrated circuit manufacturing industry.

Sernsor Sensors lays on the factor that low energy consumption and high sensitivity. Use of silicon circuit based sensors decreases the self heating and thermal coupling. Example: Si-Ge (silicon-germanium) reduces self heating and improves performance. Human has skin temperature of about 93F infrared energy with a wavelength between 9 and 10 nanometers. Therefore the sensors are typically sensitive in the range of 8-12 micrometers where electrons can be detected and amplified into signal. Example: CNT has high precision target making orientation temperature detection and measurement changes with body temperature.

Target Identification: Nanorobot has the capability for moving, sensing, manipulating and interacting with target identification for treatments of different diseases. Depending on medical applications, specific choices can be sent in terms of sensors and actuators control. The computational approach involves a multithreaded system that involves dynamic updates for real nanorobot real time sensing and activation (**Fig. 2**).

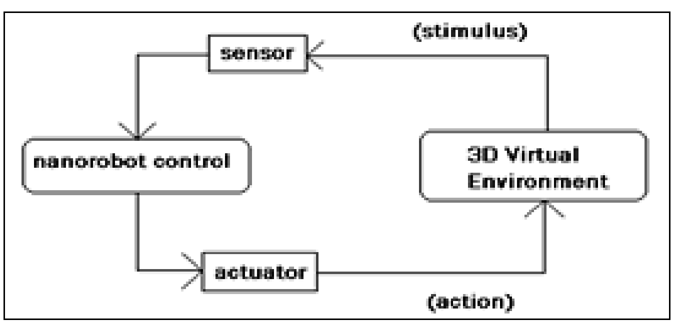

FIG. 2: INPUT STIMULUS AND ROBOT'S OUTPUT ACTION IN NANOROBOT'S DYNAMIC REAL TIME

Sensing: Based on the described hardware architecture, the nanorobot uses sensors allowing it to detect and identify nearby large objects in its environment, as well as the target regions for its task. The nanorobot includes external sensors to inform it of collisions and identify when it has encountered a chemical signal or abrupt changes of temperature for targeted areas. Hence, in order to simulate the nanorobot intervention and interaction with the workspace, we used multiple biological nanorobots, where depending on their protein demand; they will emit chemical and thermal signals.

Actuation: The nanorobots' task involves collecting various chemical compounds as predefined proteins, delivering them to specific target regions in the 3D environment. The nanorobot must, after identifying the biomolecules as proteins, use control strategies involving movement around the environment to identify and drug delivery. For the propulsion mechanism to move through the fluid, the nanorobots uses double propellers, with different velocities regarding the flow directions. Thus equation becomes: $v_{robot} = v_{fluid} + v_{force}$ with v_{force} directed along the axis of the nanorobot and with one of these magnitudes.

RESULTS AND DISCUSSION: Simulated scenario considered here is the nanorobot operating in finding target information in blood vessels. The fluid in the vessels contains red blood and tumor cells. To find out the target, nanorobot uses the chemical reorganization and color of the background. If no signal was detected, a nanorobot just keeps flowing with the bloodstream to spending power in unnecessary active locomotion. When a nanorobot detects the higher concentration signal of the target, it releases another signal to attract another nanorobot.

A nanorobot can estimate the number of nanorobots at the area by monitoring the concentration of a signal from others. It stops attracting others when the target region has enough coverage. These nanorobots are positioned according to the coverage of the target area. Then nanorobots move throughout the target area by detecting higher signal concentration. For the movement of a nanorobot, viscosity dominates through the fluid in the body. Due to the viscous forces, the nanorobots flow to the new location. The movement process consists of alternate short movements with random changes in direction. Whenever obstacles are identified, the nanorobots place to the new obstacle free positions based on the local path. After obstacle is avoided, each nanorobot will change its position based on the global path accordingly so that the new position information is broadcasted to the others.

Simulation Setup: In order to analyze the effectiveness of movement control algorithms, several simulation parameters shown in **table 1** are used. Some tests are carried out to illustrate the proposed algorithm in following the environments well.

TABLE 1: PARAMETERS FOR THE ENVIRONMENT, ROBOTS AND THE CHEMICAL SIGNAL USED IN OUR TASK

Parameter	Value
Vessel and target	R=5µm
Vessel radius	L=100µm
Target length	$L_{length=}$30µm
Fluid	ρ=1g/cm^3
Fluid density	η=10^{-2}
Fluid viscosity	$v_{avg=}$100µm/s
Average fluid velocity	T=310K
Robots	
Robot radius	1=1µm
Number density of robots	$\rho_{robot=}$ 2 x 10^{-4} robots/$(µm)^3$
Robot diffusion coefficient	D_{robot}=0.076 µm^2/s
Chemical signal	
Production flux at target	F_{target}= 56 molecules/s/$(µm)^2$
Diffusion coefficient	D=100µm^2/s
Concentration near source	1.8 molecules/$(µm)^3$
Background concentration	6x10^{-3}
Acoustic signal	
Speed of sound	v_{sound}=1.5 x 10^9 µm/s

Simulation Experiment: In order to examine the performance of the proposed obstacle avoidance algorithm, we use random obstacles in dynamic environment. **Figure 3** depicts the illustration representation of obstacle avoidance of 5 nanorobots, which is based on the global path planning and local path planning. While any robot identify the target, it send signal to rest of the target represented by **figure 4**.

FIG. 3: OBSTACLE AVOIDANCE

FIG. 4: TARGET DETECTION

CONCLUSION: Realizing applications of nanorobots to health issues raises new control challenges. The intelligent control systems for nanorobots may great impact on the development of future medical nanorobotic systems. This study has investigated the possibility of using nanorobots to investigating within human body. Nanorobots should help, through medical target identification, to improve diagnosis and provide new therapeutic procedure without ant surgery and side effects.

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