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NANOROBOTS- A PANACEA TO HIV

Manasjyoti Bhuyan[1], Swagata Bardoloi[2]
[1 2] *B.Tech Scholar, Dept. of Computer Science and Engineering, The Assam Kaziranga University Jorhat, Assam, India*
[1] *bhuyanmj@gmail.com*
[2] *swagata771@gmail.com*

Abstract - *'Nanorobot' a minute device, devised to perform specific task repeatedly and with precision at nanoscale dimensions (1nm=10^{-9}m).Nanotechnology has developed in the field of different medical purposes. Nanotechnology in the field of medical science leads to developing of nanorobots that can cure the disease in its cellular level. Currently there is no proper medicine or vaccine available for curing HIV virus, but nanorobot,an engineering of nanotechnology can be used to kill thedeadly virus. In this paper, we'll be reviewing about the nanorobot that cures an AIDS patient.*

KeyWords: **Nanoscale, Nanotechnology, HIV, WBC, Nanorobots,CD4 protein**

1. INTRODUCTION

Different fields of Robotic technology exist nowadays. Nanorobotics is one of its type. It is a field of robotics where groups of robotics and biotech engineers are developing complex robots of very small size. The nature of the components being in the nano scale, allows the researchers to mimic human behavior. The construction of the various complex parts, which constitute the robots, have been possible due to nanorobotics.

In the 1980s and 1990s, a handful of authors began speculating about the physical forms that future medical nanorobots might take. A few created artist's conceptions of their devices. During this time, only the broadest analyses of the missions and capabilities that might be desired had been attempted. Known as nanorobot pioneer, Adriano Cavalcanti is the medical nanorobotics inventor for the practical hardware architecture of nanorobots, which was integrated as a model based on nanobioelectronics for applications in environmental monitoring, brain aneurysm, diabetes, cancer, cardiology and AIDS.

2. WHAT IS HIV VIRUS?

AIDS is human viral diseases that ravages the immune system, undermining body's ability to defend itself from infections and diseases. It is caused by Human Immunodeficiency Virus (HIV).

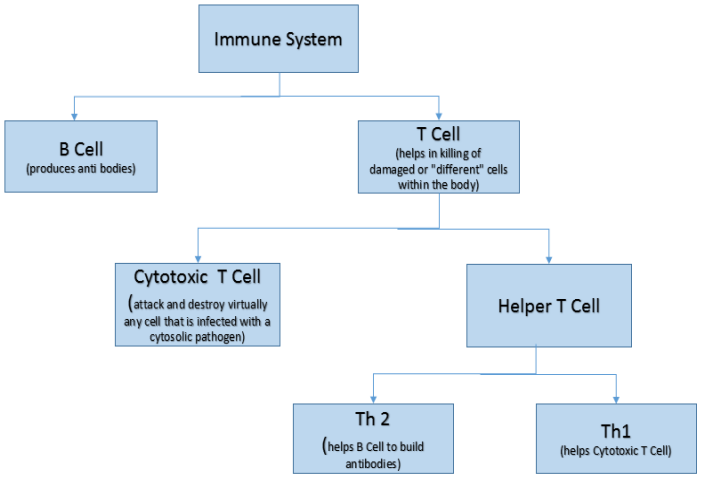


Fig-1: Human immune system

3. HOW HIV AFFECT THE HUMAN IMMUNE SYSTEM?

Whenever any foreign substance or agent enters our body, the immune system is activated. Both B-cell and T-cell members respond to the threat, which eventually results in the elimination of the substance or agent from our bodies. Normally, these actions are wonderfully protective of us. The gp 120,"recognizes" is a protein on helper T-cells named CD4, and physically associates with it. The CD4 protein is a normal part of a helper T-cell's membrane.[8]

The HIV attack the immune system by gradual eliminating the Th1 and Th2 helper T-cell subpopulation. The HIV finds the CD4 cell and get inside it and make copies of itself. Then the HIV kills the CD4 cell and the new HIV copies find other CD4 cells to get inside and start the same cycle.

4. METHODOLOGY OF ANTI-HIV NANOROBOTS

AIDS by itself is not a killer disease. The HIV virus destroys the immune system. Thereby the host system is vulnerable to small diseases which will turn into a fatal one but actually it is not a fatal disease. The HIV virus attack the WBC‟s by converting them into the HIV. Thereby all the WBC‟s are converted into HIV, so the immune system will fail. This is the reason for the death of the patient. Our idea is to convert the AIDS affected WBC‟s back into the original form of the WBC by using a Nanorobot, thereby the patient is made to have a constant amount of immune system. Nanorobot performs the inverse process of the HIV. [1]

Host WBC + HIV virus = Infected WBC

Nanorobot + Infected WBC = Restored WBC

5. COMPONENTS OF THE NANOROBOTS

- Payload –
  This void section holds a small dose of drug/medicine. The nanorobots could transverse in the blood and release the drug to the site of infection/injury.

- Micro camera –
  The nanorobot may include a miniature camera. The operator can steer the nanorobot when navigating through the body manually [2][3]

- Electrodes –
  The electrode mounted on the nanorobot could form the battery using the electrolytes in the blood. These protruding electrodes could also kill the damage cells by generating an electric current, and heating the cells up to death.

- Swimming tail – The nanorobot will require a means of propulsion to get into the body as they travel against the flow of blood in the body.

The nanorobot will have motors for movement and manipulator arms or mechanical leg for mobility. The two main approaches followed in construction of nanorobots are Positional assembly and Self- assembly. In self-assembly, the arm of a miniature robot or a microscopic set is used to pick the molecules and assemble manually. In positional assembly, the investigators will put billions of molecules together and let them automatically assemble based on their natural affinities into the desired configuration [3][4][5]. Nanorobot Control Design is the software developed for simulating nanorobots in environment with fluids which is dominated by Brownian motion [6]. The nanorobots have chemical sensors which can detect the target molecules.
The nanorobots are provided with swarm intelligence for decentralization activity. Swarm intelligence techniques are the algorithms designed for artificial intelligence of the nanorobot in which work is done collaboratively without a centralized control.

5.1 Onboard computers of Nanorobot

- Power System-
  The nanorobots uses the glucose molecules present in the human body as the power source.

- Nano Logic Processor –
  It comprises the main sensing, actuation, data transmission, remote control uploading and coupling power supply subsystem, addressing the basics for operation of medical devices.

- Sensors–
  Nanorobots will have chemical, pressure, temperature sensors, electromagnetic, magnetic, optical sensors, gravity, position/orientation sensors, and molecular recognition sites.
  In addition to that, the nanorobots will also have DNA sensors.

- DNA Sensor –
  The DNA sensor is a cantilever type. In one arm the actual sample is placed and in the second arm the sample from the WBC is placed. Even if the samples differ by a single base, it can be identified Carbon nanotube network field-effect transistors (NTNFETs) that function as selective detectors of DNA immobilization and hybridization.[8]

- RNA converter –
  It converts the RNA of the HIV virus.

- Antenna Interface –

A system for tracking an object in space comprising a transponder device connected to the object. The transponder device has one or several transponder antennas through which a transponder circuit receives an RF(radio frequency) signal. The transponder device adds a known delay to the RF signal, thereby producing RF response for transmitting through the transponder antenna. This helps to control nanorobot position.

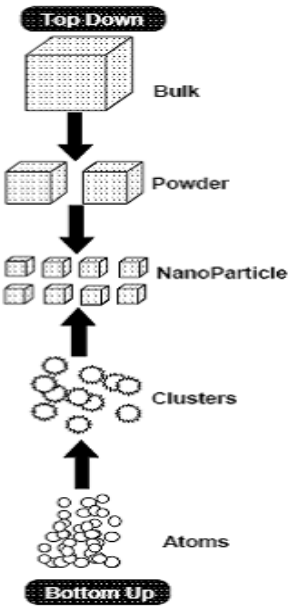
- Actuator –
  A nanoscale device used to pump fluids, open and close valves. In this model, it is specifically used to provide translational movement for the nanorobot.

6. APPROACHES

The creation of nanorobots follows two approaches -

- Top-down approach
- Bottom-up approach

The mostly followed approach for creation of anti-HIV nanorobots is the bottom-up approach. It involves assembling structures atom-by-atom or molecule-by-molecule which will be useful in manufacturing the devices.



Fig–2: Different approaches for creation of nanorobot

7. INTRODUCE THE DEVICE INTO THE BODY

We need to find a way of introducing the nanorobots into the body, and allowing it access to the operations site without causing too much ancillary damage. We have already made the decision to gain access via the circulatory system, which leaves us with a number of considerations.

Firstly the size of the nanorobots shoulddetermine the minimum size of the blood vessel that it can traverse. It should not damage the walls of whatever blood vessel the device is inand it should also not block it too much, which would either cause a clot to form, or just slow or stop the blood flow, hampering in precipitating the problem we want to cure in the first place. What this means, of course, is that the smaller the nano-machine the better. However, this must be balanced against the fact that the larger the nano-machine the more versatile and effective it can be. This is especially important in light of the fact that external control problems become much more difficult if we are trying to use multiple machines, even if they don't get in each other's way.

Secondly, we can get it into the body without being too destructive in the first place. This requires that we gain access to a large diameter artery that can be traversed easily to gain access to most areas of the body in minimal time. The obvious candidate is the femoral artery in the leg. This is in fact the normal access point to the circulatory system for operations that require access to the bloodstream for catheters, dye injections, etc., so it will suit our purposes nicely.

8. WORKING OF NANOROBOTS WITHIN THE BLOOD CELLS

A. Method 1-

In the first method the nanorobots will have biosensor to identify a particular compound. In this case the biosensor will contain a particular antibody. The gp41 and gp120 are two unique HIV envelope protein which is found in the cell membrane of the infected cell. The antigen (gp41 and gp120 protein) and antibody reaction will give the proper signal. In case of infected cell only this reaction will take place as those viral proteins are found in the cell membrane of the infected cell only. Getting the +ve signal the nanorobot will inject its nanotube into the nucleus of the infected cell and release the DNase as well as RNase

enzyme into the cell. The DNase enzyme is not sequence specific and as a result it will cleave the whole genomic DNA containing the viral genome into single nucleotides. Once the viral genome loses its sequence it loses its viral effect and after the digestion of the whole genomic DNA the cell undergoes normal programmed cell death called apoptosis. Thus the infected cell of the diseased body can be destroyed to finish off the viral genome in the body. [11]

B. Method 2-

One another method that can be implemented is that the nanorobots will have two arms that will have two arms. One of the arm will be attached to the infected WBC cell and the other one will be attached to the healthy WBC cell. The DNA sensor will send signals to the CPU present in the nanorobot to match between both the cells and it can be identified by Network field effect transistors (NTNFETs) that can function asselective detector of DNA immobilization and hybridization. If a mismatch is found between the WBC cells, then the CPU send the signal to the RNA converter to activate. Then the RNA converter converts the infected WBC that contains the HIV into DNA that is killing the virus.

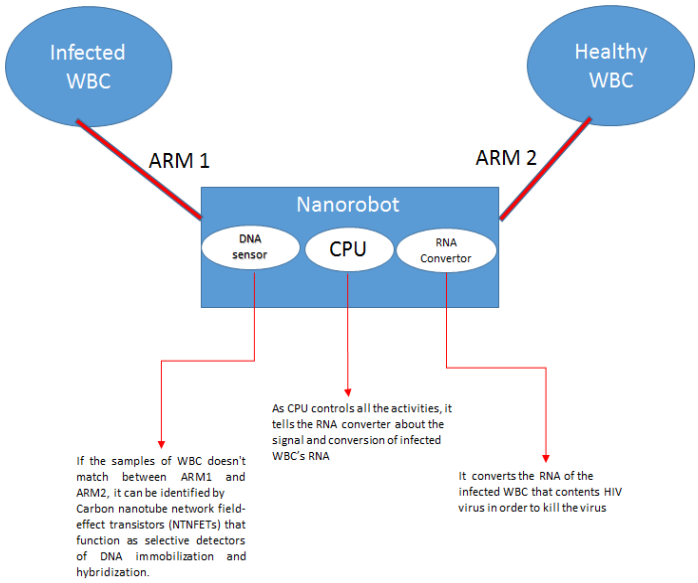


Fig-3: Structure of the nanorobot

9. MOVEMENTS AND CONTROL

One important aspect of nanoscale robots and its application in medicine is the development of control automation algorithms for their movement trajectory. Three behavioral control techniques have been considered to control the nanorobots' motions. First approach used nanorobots' small Brownian motions to find the target by random search. In second approach, nanorobot monitors for chemical concentration intensity 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 [9]. In these approaches, the nanorobots are spread across an arbitrary manner. It is difficult to obtain the optimized monitoring by applying randomize approach rather intelligent way should be incorporated. In this paper, the particle swarm optimization algorithm (PSO) is proposed as an appropriate control algorithm to control nanorobots' mobility within a human body. Obstacles avoidance is also considered to achieve the complete control strategy.

9.1Obstacle Avoidance

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. To avoid obstacles during trajectory, self-organized trajectory planning is required. Even though obstacles can be all shapes and sizes, circle representation is considered here for the simplicity. The structure of obstacles can be defined as follows.

Obstacle $=<P_{center}, P_{radium}, P_{velocity}>$..... (1)

Here, P_{center}, P_{radium} and $P_{velocity}$ are the center point, the radium and the velocity of the moving obstacle. Polar coordinate system, which is the two dimensional coordinate system in which points on a plane is determined by an angle and a distance, is used to find out the trajectory for obstacle avoidance. It can be used effectively for computing the desirable direction angle for movement trajectory of nanorobot. Each obstacle can be represented in polar coordination by following equation:

$r^2 - 2rr_i\cos(\theta - \theta_i) + r_i^2 - r^2 = 0$.....(2)

In which, r is radium of obstacle and (r_i, θ_i) is the center of the obstacle. The nanorobot will detect dynamic obstacles at real-time and get obstacles information and then determine the movement trajectory.

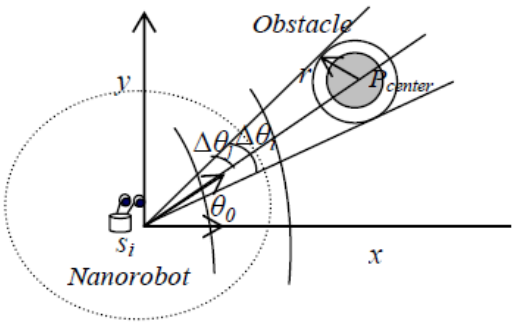


Fig-4: Obstacle in polar coordination

When a nanorobot moves, it will detect moving obstacle on a certain distance according to time Δt. Suppose an obstacle has a certain position (x_i,y_i) and both obstacle and nanorobot move with the same fluid velocity v_f (v_fx_i,v_fy_i), the new position of obstacle (xj,yj) within time Δt can be calculated as follows:

$x_j = x_i + v_f x_i * \Delta t$; $y_j = y_i + v_f y_i * \Delta t$ .....(3)

The distance Δd between a nanorobot and the center of the obstacle, Pcenter within time Δt can be calculated by using the following equation.

$$\Delta d = \sqrt{(x_j + v_f x_j * \Delta t - x_i + v_f x_i * \Delta t)^2 + (y_j + v_f x_j * \Delta t - y_i + v_f y_i * \Delta t)^2}$$
.....(4)

Prediction on the obstacle's movement in a dynamic unknown environment is one of the important factors to avoid the obstacles effectively. The time to collision Δt_c can be

$$\Delta t_c = \frac{\begin{matrix}2*(-x_i*v_fx_i - y_i*v_fy_i + v_fx_i*x_j + v_fy_i*y_j + x_i*v_fx_j \\ -x_j*v_fx_j + y_i*v_fy_j - y_{j*}v_fy_j) \\ -\sqrt{\begin{matrix}(-2*(-x_i*v_fx_i - y_i*v_fy_i + v_fx_i*x_j + v_fy_i*y_j + x_i*v_fx_j \\ -x_j*v_fx_j + y_i*v_fy_j - y_{j*}v_fy_j))^2 \\ -4*(v_fx_i^2 + v_fy_i^2 - 2v_fx_i*v_fx_j + v_fx_j^2 - 2*v_fy_i*v_fy_j + v_fy_j^2) \\ *(x_i^2 + y_i^2 - x_i^2 - 2*x_i*x_j + x_j^2 - 2*y_i*y_j + y_j^2 - 2*r_i*r_j - r_j^2)\end{matrix}}\end{matrix}}{\begin{matrix}2*(-x_i*v_fx_i - y_i*v_fy_i + v_fx_i*x_j + v_fy_i*y_j \\ +x_i*v_fx_j - x_j*v_fx_j + y_i*v_fy_j - y_{j*}v_fy_j)\end{matrix}}$$ (5)

figured out based on Δd, the distance between the obstacle and the nanorobot. Based on the collision time Δt_c, nanorobot can predict the obstacle's future position and adjust themovement trajectory. Time to collision Δt_c can be calculated as follows:

When an obstacle is encountered (figure 3), the heading of nanorobot can be adjusted to the $\Delta\theta_j$ radium, which can be represented as follows:

$$\Delta\theta_j = \arctan\frac{r}{d(s_i, P_{center})}$$ .....(6)

Here, r is radium of the Obstacle; d (s_i, P_{center}) is the distance between a nanorobot and an obstacle. Then, the trajectory of the nanorobot can be calculated by transforming Polar coordinate to Cartesian coordinate as follows:

$$x = r*\cos(\Delta\theta_i)\ ;\ y = r*\sin(\Delta\theta_i)$$ .....(7)

10. ALGORITHM

The nanorobot must use obstacle avoidancealgorithm and control algorithms involvingmovement around the environment of the search space to identify and monitor the targets. The following are the two algorithms:

A. Algorithm – Movement control[5]

Step 1: As the nanorobot moves through the search space gaining one new position based on fluid velocity, the conditional statement checks if it has enough coverage based on its neighbors.
Step 2: To be a neighbor, for each nanorobot s_i, $s_j \in S$, where i, j=1..n checks for the distance information whether the Euclidean distance between s_i and $s_j \le 1$.
Step 3: For each nanorobot s_i, calculate the coverage

value based on the neighbor nanorobots.
Step 4: If coverage value < threshold value, it will find out the new position again.
Step 5: The new position is selected randomly, then the neighbors are found out based on the new position and coverage over the new position is carried out.
Step 6: The fitness function is evaluated over the new position based on the coverage over current position and coverage over global best position.
Step 7: If the best position is found out, update the velocity and move to the next location.
Step 8: When a nanorobot detects an obstacle, it can predict the future position of obstacle due to the distance between two moving objects, Δd and time taken on movement Δt.
Step 9: The obstacle's moving distance Δd in time Δt influences the time to collision Δt_c.
Step 10: When nanorobot steps into a new location, it checks if there are dynamic obstacles in current target area.
Step 11: If this condition is true, the obstacle avoidance algorithm is initiated.
Step 12: Time to collision Δt_c is found out to predict the next position of the obstacle.
Step 13: Based on the Δt_c, nanorobot is headed to the collision free position $\Delta\theta_i$ and move to the new location.
Step 14: The position of the nanorobot is changed and fitness over current position is checked again.
Step 15: If fitness is less than threshold value, new position is carried out.

B. Algorithm for Obstacle Avoidance–

Algorithm_Obstacle_Avoidance($\Delta d, S_i, \Delta t_c, \Delta\theta_{ij}, S_j, r$)[5]

Input: S_i is the current position of the nanorobot
Output: S_j is the new best position

Step1: Calculate Δd where distance between nanorobot Si and obstacle
Step 2: Calculate time to collision Δt_c based on Δd
Step 3: Start to generate $\Delta\theta_{ij}$ based on Δt_c
Step 4. Calculate Cartesian coordinate's x_{ij}, y_{ij} from polar coordinates where
$x_{ij} = r*\text{Cos}(\Delta\theta_{ij})$;
$y_{ij} = r*\text{Sin}(\Delta\theta_{ij})$;
'r' is the radius of the obstacle ($0<\Delta\theta_{ij}<180$)
Step 5: Move nanorobot Si from x_{i1}, y_{i1} to x_{ij}, y_{ij}
Step 6: Calculate coverage of range Si to its neighbors N (S_i)
Step 7: if (coverage value > current optimum) then
Current optimum target=current selected target. Move nanorobot Si to new best position
End if
Step 8: Exit

11. CONCLUSION

Being in the era of 21st century, we could see a huge advancement in nanotechnology but this paper is just a theoretical justification. Recent advancement in nanotechnology gives us a hope of the effective use of the nanotechnology in field medical science. Currently, there is no cure of this deadly disease AIDS cause by HIV. So, if nanorobots comes into the practice it will be a huge advantage for the human kind. This paper gives the idea of the nanorobots that can kills the HIV virus; how the robot works and what are the techniques that can be used in order to move and avoid obstacles inside the human body.

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