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Simulation of AI & ML based nano mechanical embedded systems for diagnostic application development in the field of bio-medical

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Abstract

The research work that is presented in this extended abstract aims to perform a simulation of AI & ML based nano mechanical systems for diagnostic application development in the field of bio-medical engineering, i.e., we simulate a nano-robot that could be used for the detection of cancerous diseases in human beings. We use some nano-technology based simulation tools such as the nano-hive software for the design & simulation of robots, further to use the simulated robot to detect the cancerous cells and give an intimation to the doctor and to the patient that the patient has been affected with cancer and if possible bring out the cancerous cell out of the human body. Simulation is carried out using nano-hive software tool & the results are presented. In this research work, we have developed some mathematical models for the dynamical movements of the nano-robots, we also simulated a nano-robot using simulation tools like nano-hive or cadence or synapses tools. Once simulated & given a job to detect the cancer cells & destroy them, the effect of achieving the task is seen. Different simulation parameters were considered in the design process in the software. If there should be an occurrence of dynamic focusing on, nanoparticles containing the chemotherapeutic specialists were planned in such a manner as they straight-forwardly communicate with the deserted/infect cells and do the action preset.

Keywords: Nano-robot, artificial intelligence, machine learning, simulation, cancer, bio-medical, embedded

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1. Introduction

In the fight against cancer disease, the, early detection is a key factor for successful treatment and to save precious human life. The research work presented in this extended abstract relates to such an application-oriented work w.r.t. the simulation, design and development of nano-robots for cancer cure therapy and diagnostic applications in human beings using artificial intelligence and machine learning tools with the help of software tool studies. The main objective of the research work is to carry out the following, which is combined in the form of 4 well-defined objectives as (1) To simulate a miniaturized nano-robot to detect the cancerous cell using simulation tools like nano-hive and cadence tools using the following concepts such as Locomotion, Propeller, Cilia/flagellate, Electromagnetic pump, Jet Pump, Membrane propulsion, Crawl along surface, Navigation, Ultrasonic parts, Radioactive dye parts, Power actuating device, Sources within the body, Generation of power from the bloodstream (2) Studying the behaviour of the cancerous cells and to halt their behavioural growth by detecting that the cell is being affected with the cancer disease (3) To kill or dis-infect the cancerous cell by injecting anti-cancerous nano-particle and to make it inactive and (4) Devise some strategies to bring them out of the human body by collecting them.

The above-mentioned goal of our research work is met by following the 4 important measures listed below, one by one (1) Determine the nano-robots mode of entry into the human body and developing a nano-robot's propulsion system, at the same time by finding ways to hold a set location when working (2) Determining how to use the system and finding a suitable power source for the nano-robot, at the same time, determination of the exact location of the infected cell for 2 cases, viz., when the infected cell is moving along the flow of fluid and when the infected cell is moving against the flow of the fluid (3) Identifying methods for locating compounds that the nano-robot can remove and further to identify the methods for removing the drug from the body (4) Continually observing the body and providing updates on the cancer cell's destruction and finally, to make the infected cell in-active or to bring it out the human body.

This research article is organized in the following manner as follows. A brief background about the related works was presented in the previous paragraphs in the introductory section. Section 2 gives an overview of the related literature review w.r.t. the work that is being taken up in this paper. Section 3 gives the history about the cancer cells. Section 4 gives a light into the materials and the methods that are being used in the design process. The ant colony optimization techniques that are used in the proposed work is presented in the section 5. Flow Chart Development is presented in section 6, which is followed by the design methodology in section 7. The results and discussions are presented in section 8, followed by the brief conclusive remarks in the section 9 and the references.

2. Literature review

A number of researchers have worked on the similar topic and here, a few of such works have been presented in a nutshell. To overcome this, the idea of nano-technology gives high affectability, explicitness and multiplexed estimation limit and has along these lines been worked for the identification of extracellular malignancy bio-markers, mutation aspects and cancer cells in this work. Among the cardinal steps towards ensuring optimal cancer treatment, which is going to be used in our work are early location of malignancy cells and medication application with high particularity to lessen poison levels. Because of expanded fundamental poison levels and unmanageability with customary disease demonstrative and helpful devices, current successful strategies like use of nano-robots in nanotechnology are being employed to improve diagnosis and mitigate disease severity here in this work.

The concepts what we are developing using nano-technology is going to be used for several cancer types to reduce the invasiveness of cancerous cells while sparing healthy cells at the target site. It is also planned to use nanomaterials such as carbon nanotubes, polymeric micelles, and liposomes in cancer cell identification, destruction, and removal from the body. But, the current technological developments in a developing country like India hinder this growth due to the lack of infrastructural facilities. Hence, in this context, we have taken up the amalgamation of nano-technology and the nano-medicine to save the mankind from this world's most infectious disease to which a large number of people are falling prey and develop some strategies in the field of modelling, design, development of nano-robots for the cure of cancer disease (only simulation work we are planning to do using some software and if time permits, we shall do the hardware).

The blend of nanotechnology into prescription is likely going to get some new troubles therapeutic treatment as the nano-robots are a heavenly vision of medication in future. The most extraordinary nanomedicine incorporates the use of nano-robots as limited scale experts to murder the infection. A champion among the most reasonable and practically possible achievements is the remedy for development which is one of the essential places of this examination work. Nano-robots could convey and convey a lot of hostiles to malignant growth drugs into dangerous cells without hurting sound cells, diminishing the results identified with current treatments. These nano-robots will have the ability to fix tissues, clean veins and aeronautics courses, change our physiological limits.

In this research work that is going to be done, we plan to develop some mathematical models for the dynamical movements of the nano-robots, we also simulate a nano-robot using simulation tools like nano-hive or cadence or synapses tools. Once simulated and given a job to detect the cancer cells and destroy them, the effect of achieving the task is seen. Different simulation parameters are going to be considered in the design process in the software. If there should be an occurrence of dynamic focusing on, nanoparticles containing the chemotherapeutic specialists are planned in such a manner as they straight-forwardly communicate with the deserted/infect cells.

Koleoso worked on the micro or the nano-scale magnetic property based robots for various types of bio-medical applications in his paper in [1]. They devised several alternative biomedical applications in their work, as well as suggestions for some of the systems that have the ability to perform other functions. Although the field of small-scale robot work is highly creative, more concerted efforts are needed to improve the functionality and reliability of these machines, especially in clinical applications, according to the findings of this report. Finally, further works were made in order to ensure commercialization of these instruments in their article in [1].

Nanobots: Development and future – a superb article was coined by the group of authors led by Jose Roberto Vega Baudrit *et.al.* in their article in [2]. They presented the next generation of nano-devices how they are used to revolutionize patient diagnosis and drug delivery technology. They proposed several obstacles in developing this technology, not only from a mechanical, biological, and physicochemical standpoint, but also in terms of the dangers of using these nanoscale materials and technologies, as well as their contact with the environment and humans. The aim of this review article was to describe nano-bots, their technologies and developments, as well as their medical applications, particularly in the field of cancer care.

In their paper [3], Yamaan Saadeh focused on Nano-robotic Applications in Medicine - Latest Ideas and

Prototypes. The aim of this paper was to provide an overview of the evolving field of nano-robotics in medicine, as well as a study of nano-robotics possible applications in fields ranging from neurosurgery to dentistry [3]. An application of nano-technology in cancer diagnosis & in the therapy - Cancan Jin et.al. conducted a Mini-Review in their application-oriented paper [5].

The authors defined the most widely used nano-materials in cancer diagnosis and treatment. They reviewed the problems associated with the various nanomaterials, which restricted their applications and hindered their translatability into the clinical setting in some cancer types [5]. They also highlighted the suitability of these nanomaterials for cancer treatment based on their physicochemical and biological properties. In summary, they aimed to demonstrate the core benefits of nanotechnology as well as the limitations of its use to address cancer clinical needs [5].

From individual nanoparticles to nano-machines and nano-robots, nanomaterials are being used to cure cancer was studied by lexandre Loukanov *et.al.* in [11]. As discussed in [11], the aim of this important analysis was to concentrate on the latest use of clinically accepted nanoparticles for cancer theranostic, nano-vaccines, and gene therapy delivery platforms, which included inorganic, metal, and polymer nanoparticles, nanocrystals, and various drug delivery nanosystems (micelles, liposomes, micro-capsules, and so on). Arizona State University (ASU) scientists, working in conjunction with authors from the Chinese Academy of Sciences' National Center for Nanoscience and Technology (NCNST), have successfully programmed nano-robots to shrink tumours by cutting off their blood supply.

Shaolong Shi *et al.,* developed Nano-robots-assisted Multifocal Cancer Detection with a Multimodal Optimization Perspective in [13]. When the biological target feature is aligned with the blood flow velocity profile triggered by tumor-induced angiogenesis, the authors proposed a detailed numerical illustration to illustrate the efficacy of the NGA-inspired MCDP. However, they did not work on enhancing the algorithm's efficiency in order to detect all cancer areas with a sufficient number of nano-robots, it was also necessary to investigate the effect of nano-robot non-idealities such as finite lifetime, imprecise guiding and unreliable monitoring.

The authors of [14], led by Tianshu Chen *et.al*., focused on DNA Nanotechnology for Cancer Diagnosis and Treatment, showing how DNA could be used to identify and destroy cancer cells. The authors outlined recent advances in DNA nanotechnology for the fabrication of practical and intelligent nanomaterials, as well as the technology's potential applications in cancer detection and treatment [14]. In [15], Rouhallah Ravanshad *et al*. investigated the use of Raman scattering-based methods to diagnose cancer using Sir C.V. Raman's famous scattering phenomenon.

The key aim of this article was to incorporate some of the most common nanotechnological cancer detection methods using Raman techniques. Furthermore, they have reviewed some of the more common and even more studied cancers, such as breast and colorectal cancer, as well as several interesting nanostructures, especially as SERS nano-tag, special cancer biomarkers, and related approaches. Their key goal was to use Raman techniques to apply the most common nanotechnological approaches in cancer detection [15].

In their article in [4], Saxena et al., concentrated on the nature, architecture, and implementation of nano-robotics in oncology. The aim of this article was to describe the architecture of nano-robots and their role in oncotherapy in a concise manner. While nano-robot works is still in its early stages, the potential of such technologies is limitless. In [6], Mitra Venkatesan worked on some of the topics of the use of nano-robots for cancer treatment. An individual seeking nano-robotic care should presume to be totally ignorant of the molecular devices at work within them, save for the rapid change in their health. As a result, the authors proposed a report on diverse approaches to cancer treatment using nano robots in their article in [6], but there was no novelty and no new methods proposed, it just highlighted some of the works that could be done in future with the help of nano-robots.

Sarath and his colleagues focused on nano-robots as a potential diagnostic and treatment system in their paper [7]. Their paper focused on the use of nano-robots in the diagnosis and treatment of diseases such as cancer, heart disease, diabetes, and gout. This was a review paper that led us to recent nano-robot studies in biomedical applications and helped us to select the work that we had undertaken in this paper [7]. Devasena Umai *et.al.* conducted a study on DNA nano-bots – a novel tool for cancer treatment in the Indian context in their paper in [8]. Application of Nanotechnology in Cancer was presented in an excellent article in [9] by the team of authors led by Hirendra N. Banerjee and his group. This article addressed the effect of nanotechnology on cancer, with a focus on biomarker identification, imaging for diagnosis, and its role in therapeutic action, but it did not include any detail on the methodologies that could be used for cancer detection [9].

Nano-bots in cancer detection and treatment was studied by the group of Sandeep et al., in [13]. Many academic scientists have sought to create a variety of chemotherapy solutions, as well as actuators and energy supplies for mini drones, over the last few decades. However, nanoscience and nanotechnology engineering has come up with an excellent concept of using nano robots that use body heat and chemicals as fuel to destroy tumour cells based on the cadherin signal, which is a breakthrough in the medical field and an alternative to chemo and radio therapy to cure cancer cells. It has been shown that nanotechnology can assist in the resolution of one of the most deadly and complex problems without causing any discomfort or mutagenic side effects [13].

The authors of [10], led by Kumar Bishwajit and his colleagues, experimented on the principles of Nano-technology in Cancer Drug Delivery and Targeted Targeting and came up with positive findings. Their study focused on nanoparticles’ ability to recognize cells using a variety of techniques with novel distinguishing properties that set them apart from previous anticancer treatments. It also addressed how nanoparticles carry particular drugs within cells, citing numerous promising studies, and how nanoparticles eliminate the side effects of traditional cancer treatments with targeted cancer care [10]. Similarly, a number of authors had worked in the similar area, but only the best of them have been highlighted in this context, but many of them have lot of drawbacks or dis-advantages which were posing a serious threat to the mankind. Some of them have been identified and novel algos will be created in order to neutralize the same and propose some novel concepts in the design and development of nano-bots to cure cancer disease in human beings.

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Some of the drawbacks are the medical technology is not that much developed in our country compared to that of the advanced countries like the US, UK and the European countries. Similar to the works outlined by numerous writers in the preceding paragraphs and section, several authors around the world have continued to work in the area of using nano machines to cure cancer to this day. Some of the shortcomings of previous studies will be considered in our research work, briefly reviewed, and algorithms will be built to solve some of the limitations of current algorithms and the design of curing therapies. The work is going to be verified through effectively obtained simulation results using the sophisticated Nano-hive and Cadence tools in order to substantiate the problem undertaken.

3. Cancer Cells History

Cancer develops in the cells of the body and is powerful to disrupt the body's various parts owing to aberrant and uncontrolled development. In cancer cells oxygen concentration is very low compared to normal cells and also the pH gets affected. Breast cancer affects both men and women, however females are likely to be affected. Breasts are divided as: fatty breast and glandular breast. The breast is defined as fatty breast whenever the number of fat tissues is more than that of fibro glandular tissues, and glandular breast when the amount of fibro-glandular tissues surpasses the quantity of fatty tissues. Breast cancer develops when the mammary cells grow, alter, and proliferate uncontrollably, resulting in tumors or masses of additional tissue.

Tumors are solid lumps that can be malignant or benign. Malignancy is indeed one of the highest common cancers in the world. It is the most prevalent type of cancer that recurs and kills people. Breast cancer is the most prevalent effect in women, and it is also the tumor that causes far more deaths. Only by being able to spot symptoms early could the life expectancy be increased. To detect cancer soon, accurate and unwavering procedures must be used to distinguish between malignant tumor and benign tumours. Unlike benign tumours, malignant breast cancer cells are considered dangerous and can result in death.

4. Materials and methods

The materials used are C in the design of the nano-robot along with some specifications. Basic constructional features of a Nano-bot that is taken into consideration during the design process are – Nano-robot has a C-nanotube body, A bio-molecular n-motor that propels it and peptide limbs to orient itself, Composed of biological elements such as DNA and proteins, genomes. Hence, it can be easily removed from the body, Sensors, molecular sorting rotors, fins and propellers, 6 DOF, Sensory capabilities to detect the target regions, obstacles, C is the principal element comprising the bulk of a medical nano-robot. The chemotactic sensor which is molecule dependent helps in detecting the cancer cells. The diamond being the chemically inert material is used as an exterior material for the nano-robot [25].

Nano-robots also respond to acoustic signals and payloads of upto 2000 siRNA molecules are required for a 70nm diameter tumor. The software used is the nano-hive simulation tool. NanoHive-1 is a modular nanosys-simulator used for modeling the physical world at a nanometer scale. Purpose of the simulator is to act as a tool for the study, design, simulation, experimentation and development of nano and biological entities [25].

5. Ant colony optimization techniques

Ant colony optimization is a look for a particular object, approach for which a particular identity has been trained for. This algorithm mimics the behaviour of ants while looking for food. While looking for food, ants travel distances and in order to return to the nest, they follow the path by tracing the chemical which is left behind by them called, "pheromone". Usually, ants tend to follow the path with the higher concentration of pheromone chemical. The point to be noted is pheromone evaporates over the time and this could mislead many ants, hence ants take the path travelled by more ants leaving behind the high concentration of pheromone. Just like ants, nano-robots are also trained in such a way that they communicate with each other on finding the cancer cells and kill them. Nano-robots embrace a different migration path with a random unit vector r after travelling for time *T* given by,

Migration path = b * bias direction +(1 – b) * r

İf *b*, the bias parameter is 1, then the direction of nano-robot is predictable and consistent and if *b* is 0 then migration path is unpredictable, it could be brownian. Nano-robots can adhere to each other within a set interaction distance (usually a multiple of their radius), so that they can communicate with each other. Basically, it consists of two components, worker nano-robots and cargo nano-robots. Worker nano-robots have attractant and specific amount of oxygen information present in the cancer cells which guide them to look for breast cancer cells. After finding the cancer cells, worker nano-robots (red) look for cargo nano-robots (blue), form focal adhesions, and transport payload to oxygen-depleted tissue areas. They discharge their payload and restart their extensive search for further cargo, once they reach an adequately low oxygen location. Cargo cells that have been delivered secrete a chemotherapeutic chemical that can kill tumour cells in the area. The following points are going to be considered while designing of the nano-robots for our applications.

- Worker nano-robots search for breast cancer cells depending on the content of oxygen availability. The oxygen content is low in cancer cells compared to normal cells.
- Once the cancer cells are detected, the worker nano-robots form a focal adhesion with the cargo nano-robots to release the payload.
- With the help of cargo nano-robots, the worker nano-robots deliver the payload present in the cargo nano-robots.
- Worker nano-robots check if the released payload is sufficient to kill the cancer cells, if not, they start releasing more payload until the cancer cells are killed.

6. Flow chart development

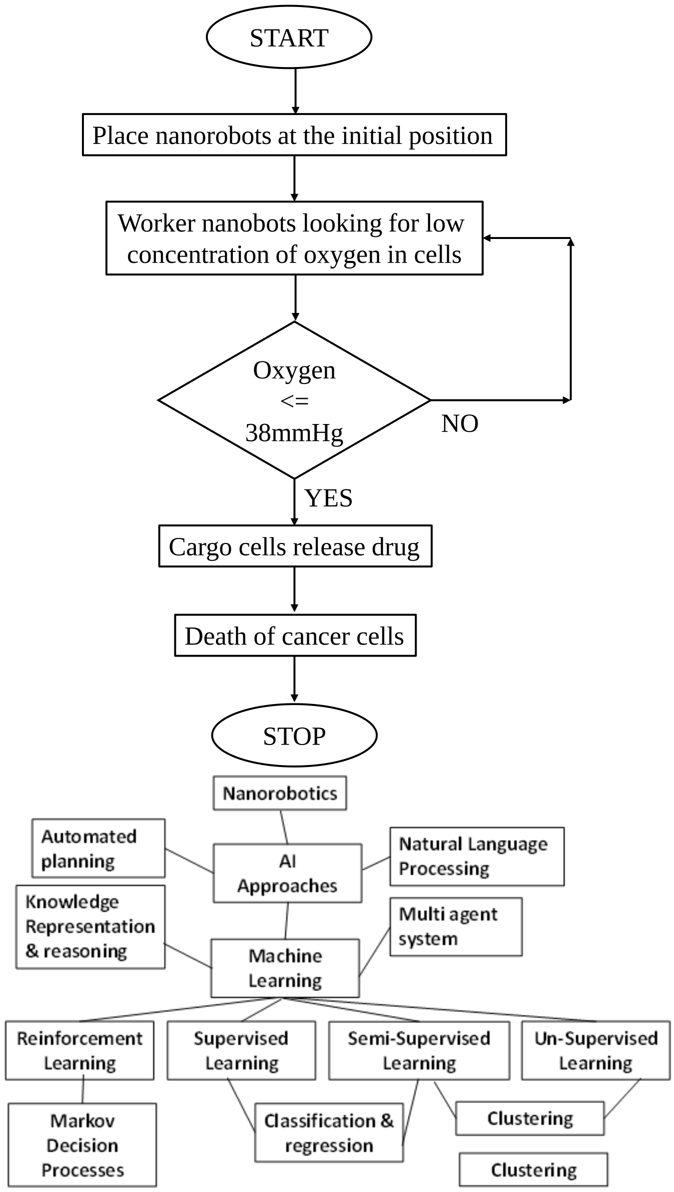

Fig. 1: Flow chart of the proposed ACO-Ant Colony Optimization and the corresponding block-diagram

The Fig. 1 gives the proposed flow chart of the ACO-Ant Colony Optimization that is going to be implemented in our research work. Some of the symbols and the variables that are used in the work are explained as below.

7. Design methodology

Some of the parameters that are being used in the design process are reiterated as follows.

Focal adhesion (F): Cell-cell focal adhesions are modelled as spring-like forces. Location x_i and x_j of two cells i and j where cell i is attached to cell j by spring force forming focal adhesion, which is modelled as

$$F = e\left(x_j - x_i\right)$$

where *e* is the elastic coefficient.

Worker nano-robots: To simulate wear and tear to nano-robots a particular death rate can be set although worker nano-robots do not proliferate. Worker nano-robots pass through dense cellular sections more easily compared to cargo nano-robots. The mode of energy source of nano-robots is the oxygen.

The worker cells which are unattached to cargo cells have their migration bias direction as:

$$\text{Bias direction} = \alpha\, t$$

Here, α is the gradient operator which points towards the chemical factor of higher concentrations, and *t* is the chemo-attractant.

Chemo-attractant (*t*): This is the chemical given out by cargo nano-robots by worker nano-robots to help in chemotaxis process. The chemo-attractant is assigned a length scale of 100 µm.

The diffusion length scale is an important aspect in chemical diffusion. Diffusion aids in the propagation of a signal over lengthy ranges, whereas decay (and uptake) destroys the signal and slows its progress. The characteristic distance *L* that a chemical signal travel is determined by a competition between these effects.

$$L = \sqrt{\frac{d}{\beta}}$$

where *L* is length scale, *d* is the diffusion coefficient and β is the decay and uptake coefficient.

In densely packed regions, *L* is 100 µm. Worker nano-robots which are attached to cargo cells can have their migration bias direction as:

$$\text{Bias direction} = -\alpha\, \lambda$$

where λ is the concentration of oxygen.

Oxygen (λ): This the concentration of oxygen consumed by cancer cells based on which the worker cells find the cancer cells. A 30 mm of Hg concentration of oxygen along with length scale of 1000 µm, in densely packed regions the cancer cells take the length scale of 100 µm.

Chemotherapeutic (*f*): It is the chemical released by cargo nano-robots to kill cancer cells. It is usually assigned to a value of 80 µm of length scale.

8. Results and discussions

Simulations are carried out in the Jupiter environment, the coding is done and run, the simulation results are observed as shown in the figures from Figs. 2 to 8 respectively. Nano Systems Simulator Tool Material - C Nano-tubes is used for the building of the nano robot. Jupiter is a modular simulator used for modeling the physical world at a nanometer scale (adv: model the DNA/ribosomes), here, the medical nano-robot (MNR) navigation is moving along the x-direction. Fig. 5 gives the representation of predicted buckling mode-shapes actual buckling mode-shape predicted using simulations; result of a simulation designed to test various distributed computing mechanisms; While just a test, it’s still an interesting simulation to watch; A diamonded carbon “knife” is pushed down on the nanotubes with a 5 nN force; Will the knife cut through the nanotubes? The system comprises ~20,000 atoms and runs for 5.5 ps of sim time, which can be seen in the Fig. 7.

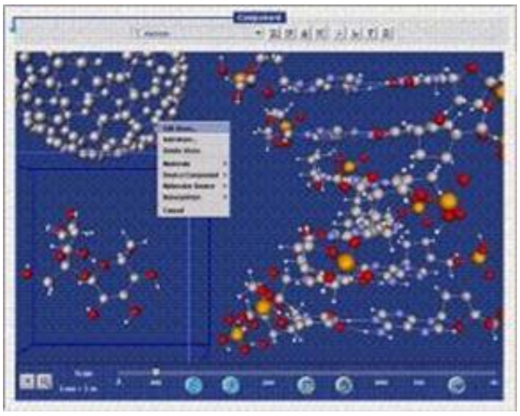

Fig. 2: Front end layout of the software tool

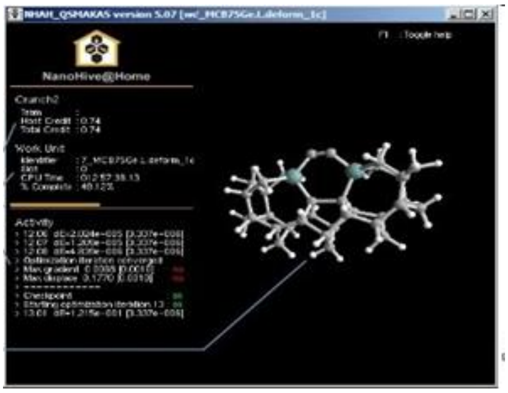

Fig. 3: Building of the nano-robot using ribosomes and carbon nano tubes

Fig. 4: Simulated Motion of the designed and developed Nanobot using Jupiter environemnt

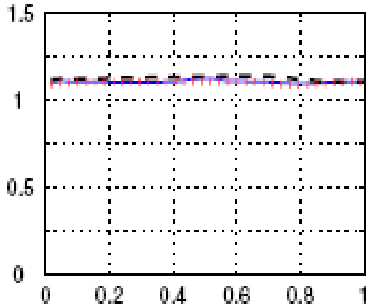

Fig. 5: Movement of the *n*-bot along the *x*-direction

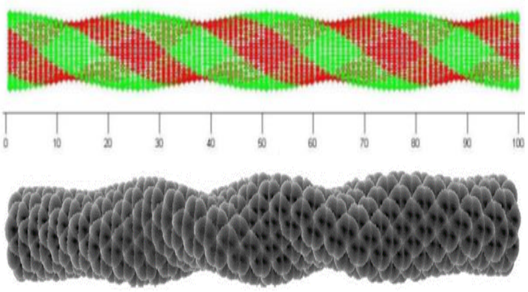

Fig. 6: Buckling modes and the predicted modes being the same, thus providing us the effeciency of the methodology that is being developed using the software tool

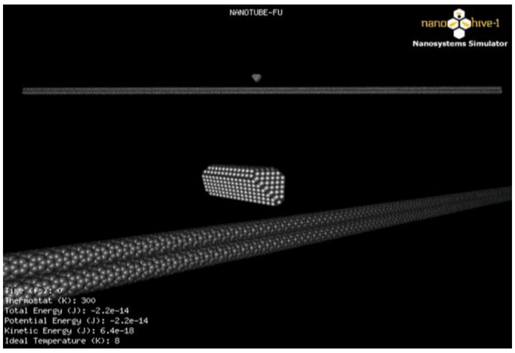

Fig. 7: Designed *n*-bot moving in the vertical direction

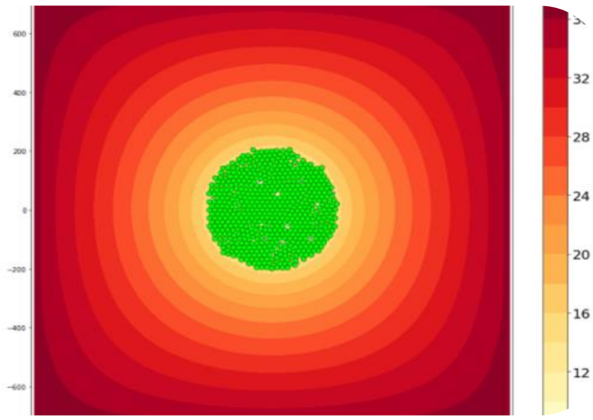

Fig. 8: Cancer cells (green in color)

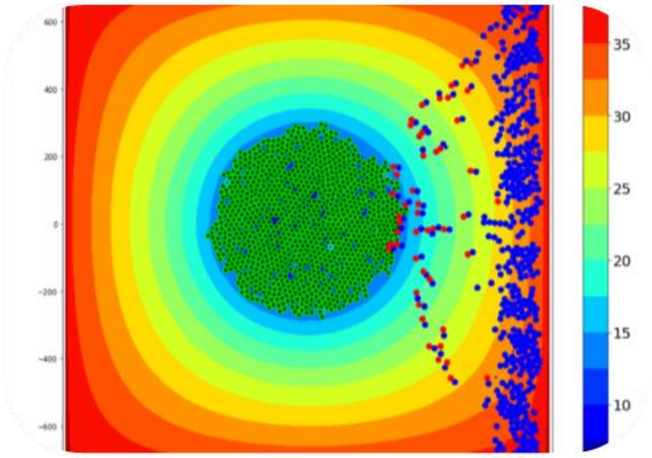

Fig. 9: Worker nanorobots (red in color) attacking cancer cells

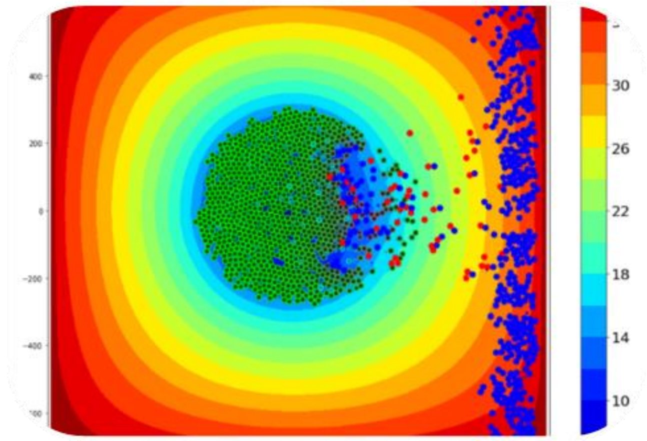

Fig. 10: Worker nano-robots delivering drugs to the affected part

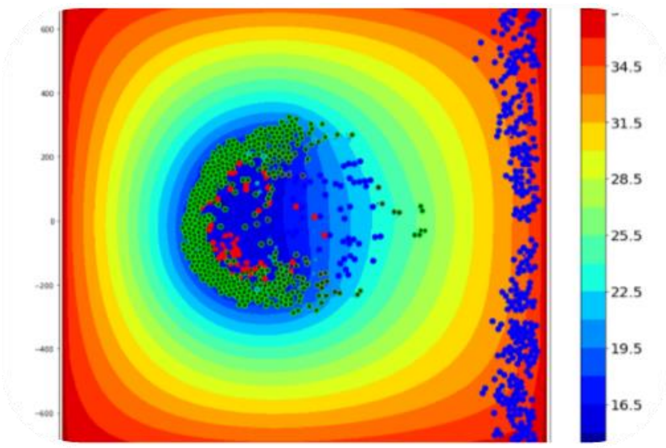

Fig. 11: Death of cancer cells due to the incorporation of the proposed ACO technique

Figure 8 shows the simulation of breast cancer cells (green in color), worker nanorobots start looking for cancer cells with the help of ant colony optimization algorithm. As the concentration of oxygen in cancer cells is low, the worker nanorobots look for the low concentration of oxygen. On finding the cancer cells, the worker nanorobots with the help of cargo nanorobots attack the cancer cells. Fig

5 shows 1557 agents (nano-robots) attacking the cancer cells. After attacking, worker nano-robots (red in color) form focal adhesion with cargo nano-robots (blue in color) to deliver the payload which is carried by cargo nano-robots as shown in Fig 10. After delivering the payload, cancer cells are killed as shown in the Fig. 11.

9. Conclusions

A small review of the research work related to the design and development of nano-robots was presented here. This research work is developed w.r.t. rural community with less experienced doctors even in the field of cancer detection and its diagnosis in the field of bio-medical engineering, i.e., it has got wide applications in the field of bio-medical engineering that too in the detection of cancerous cells as the current techniques such as the chemotherapy and the other medical activities causes lot of nausea, hair loss, vomiting, stress, etc. Cancer is a deadly disease where the cells replicate uncontrollably and spread to other parts of the body. As a result, its very important to detect the cancer in the early stages. The traditional methods like chemotherapy and radiotherapy don’t cure the disease completely and also they have many side effects and the recovery time for a patient is also too long. Hence the nanorobots simulated not only cure the cancer completely but also there are no side effects. The results show that by using Ant colony optimization algorithm, the working of worker nanorobots and cargo nanorobots and the way they communicate with each other to kill breast cancer cells.

References

[1] M. Koleoso, X. Feng, Y. Xue, Q. Li, T. Munshi and X. Chen. (2020). Micro/nanoscale magnetic robots for biomedical applications. Materials Today Bio. 8: 100085.

[2] B. Gutierrez, C.V. Bermúdez, Y.R.C. Ureña, S.V. Chacón and J.V. Baudrit. (2017). Nanobots: development and future.

[3] Y. Saadeh and D. Vyas. (2014). Nanorobotic applications in medicine: current proposals and designs. American journal of robotic surgery. 1(1): 4-11.

[4] S. Saxena, B.J. Pramod, B.C. Dayananda and K. Nagaraju. (2015). Design, architecture and application of nano-robotics in oncology. Indian Journal of Cancer. 52(2): 236.

[5] C. Jin, K. Wang, A. Oppong-Gyebi and J. Hu. (2020). Application of nanotechnology in cancer diagnosis and therapy-a mini-review. International Journal of Medical Sciences. 17(18): 2964.

[6] M. Venkatesan and B. Jolad. (2010). Emerging Trends in Robotics and Communication Technologies (INTERACT). In International Conference on: IEEE: 258-264.

[7] K.S. Sarath, P.N. Beena and A. Elessy. (2018). Nanorobots a future device for diagnosis and treatment. Journal Pharm Pharmaceutics. 5(1): 44-49.

[8] U. Devasena, P. Brindha. and R. Thiruchelvi. (2018). A review on DNA nanobots: A new techniques for cancer treatment. Asian Journal of Pharmaceutical and Clinical Research. 11(6): 61-64.

[9] H.N. Banerjee, and M. Verma. (2008). Application of nanotechnology in cancer. Technology in cancer research and treatment. 7(2): 149-154.

[10] K.B. Sutradhar and M. Amin. (2014). Nanotechnology in cancer drug delivery and selective targeting. International Scholarly Research Notices.

[11] A. Loukanov, S. Nikolova, C. Filipov and S. Nakabayashi. (2019). Nanomaterials for cancer medication: from individual nanoparticles toward nano-machines and nano-robots. Pharmacia. 66: 147.

[12] Arizona State University. (2018). "Cancer-fighting nano-robots programmed to seek and destroy tumors: Study shows first applications of DNA origami for nanomedicine". Science Daily.

[13] S. Sandeep, B.T. Gururaj, A.Y. Deepak, S. Sandeep and K. Nitish. (2015). Nanobotz in Cancer Detection and Trearment. Journal of Medicine and Pharmaceutical. 1: 7-14.

[14] T. Chen, L. Ren, X. Liu, M. Zhou, L. Li, J. Xu and X. Zhu. (2018). DNA nano-technology for cancer diagnosis and therapy. International Journal of Molecular Sciences. 19(6): 1671.

[15] R. Ravanshad, A.K. Zadeh, A.M. Amani, S.M. Mousavi, S.A. Hashemi, A.S. Dashtaki and B. Zare. (2018). Application of nanoparticles in cancer detection by Raman scattering based techniques. Nano Reviews and Experiments. 9(1): 1373551.

[16] V. Agrahari, V. Agrahari, M.L. Chou, C.H. Chew, J. Noll and T. Burnouf. (2020). Intelligent micro-/nano-robots as drug and cell carrier devices for biomedical therapeutic advancement: Promising development opportunities and translational challenges. Biomaterials. 260: 120163.

[17] T.J. Anchordoquy, Y. Barenholz, D. Boraschi, M. Chorny, P. Decuzzi, M.A. Dobrovolskaia and D. Simberg. (2017). Mechanisms and barriers in cancer nanomedicine: addressing challenges, looking for solutions.

[18] F. Bray, J. Ferlay, I. Soerjomataram, R.L. Siegel, L.A. Torre and A. Jemal. (2018). Global cancer statistics 2018: GLOBOCAN estimates of incidence and mortality worldwide for 36 cancers

in 185 countries. CA: a cancer journal for clinicians. 68(6): 394-424.

[19] S. Tran, P.J. DeGiovanni, B. Piel and P. Rai. (2017). Cancer nanomedicine: a review of recent success in drug delivery. Clinical and translational medicine. 6(1): 1-21.

[20] F. Ye, Y. Zhao, R. El-Sayed, M. Muhammed and M. Hassan. (2018). Advances in nanotechnology for cancer biomarkers. Nano Today. 18: 103-123.

[21] K.B. Sutradhar and M. Amin. (2014). Nano-technology in cancer drug delivery and selective targeting. International Scholarly Research Notices.

[22] A.P. Sherje, M. Jadhav, B.R. Dravyakar and D. Kadam. (2018). Dendrimers: A versatile nanocarrier for drug delivery and targeting. International Journal of Pharmaceutics. 548(1): 707-720.

[23] K.B. Sutradhar and M. Amin. (2014). Nanotechnology in cancer drug delivery and selective targeting. International Scholarly Research Notices.

[24] B.M. Biswal and Z. Yusoff. (2017). Application of nanotechnology in cancer treatment. In Engineering Applications of Nanotechnology. Springer, Cham. 269-311.

[25] B.H. Raghunath, H.S. Aravind, N. Praveen, P. Dinesha and T.C. Manjunath. (2021). Mathematical Modeling and Simulation of a Nanorobot Using Nano-hive Tool for Medical Applications. In Nanoelectronics, Circuits and Communication Systems. Springer, Singapore. 325-345.