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NANOROBOTS CONTROL ACTIVATION FOR STENOSED CORONARY OCCLUSION

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Abstract:

This paper presents the study of nanorobots control activation for stenosed coronary occlusion, with the practical use of chemical and thermal gradients for biomedical problems. The recent developments on nanotechnology new materials allied with electronics device miniaturization may enable nanorobots for the next few years. New possibilities for medicine are expected with the development of nanorobots. It may help to advance the treatment of a wide number of diseases: cardiovascular problems, neurosurgery, cancer, diabetes and new cell therapies. The implementation of new methodologies to help on manufacturing analyses and system design for the development of nanoscale molecular machine is one of the most important fields for research. The use of 3D physically based simulation in conjunction with clinical data may provide ways to design practical approaches for control and transducers development.

Key words: Cardiology, CMOS, medical nanorobotics, mobile nanorobot, molecular machine, multi-sensorial simulators,nanoelectronics,nanomanufacturing design, NEMS, photonics.

Introduction

The advent of nanotechnology is expected to enable automated molecular machines with embedded nanoscopic devices providing new tools for medical procedures.The present work is an innovative approach to advance the study of biomedical treatments using nanorobots for coronary atherosclerosis problems. To evaluate efficient ways of activation and control of nanorobots, This work demonstrates how chemical and thermal parameters could be successfully applied to achieve a suitable control strategy for nanorobots, and trigger their actuation upon target areas. We used computer aided design tools such as Computational Fluid Dynamics (CFD) including the main parameters required for the investigation at nanoscopic levels. The simulation included its visualization with 3D real time analyses using the software Nanorobot Control Design (NCD) to perform a predefined set of tasks, based on environment sensing and trigger behaviors. Simulation studies based on numerical results defining design strategies, capabilities and limitations,provide a better understanding on nanorobots behavior and manufacturing feasibilities.

Medical Applications

Nanorobots are expected to enable new treatments for patients suffering from different diseases, and will result in a remarkable advance in the history of medicine. Recent developments in the field of biomolecular computing,have demonstrated the feasibility of processing logic tasks by bio-computers. This is a promising first step to enable future nanoprocessors with increased complexity. Studies targeted at building biosensors and nano-kinetic devices,required to enable medical nanorobotics operation and locomotion, have also been progressing.In recent years, the potential of nanotechnology has indeed motivated many governments to devote significant resources to this new field.

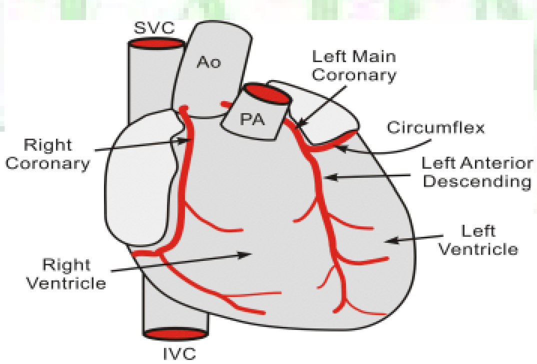

Figure 1: The coronary arteries are one of the most common sites for the localization of atherosclerotic plaques.

. In order to build electronics at nanoscales, firms are collaborating to produce new nanoproducts. Such companies include IBM, PARC, Hewlett Packard, Bell Laboratories, and Intel Corp., to name a few.The use of nanorobots may advance biomedical intervention with minimally invasive surgeries , and help patients who need constant body functions monitoring, or ever improve treatments efficiency through early diagnosis of possible serious diseases. Nanorobots will be applied in chemotherapy to combat cancer ,through precise chemical dosage administration, and a similar approach could be taken to enable nanorobots to deliver anti-HIV drugs. Nanorobots could be used to process specific chemicalreactions in the human body as ancillary devices for injured organs. Monitoring diabetes and controlling glucose levels for patients will be a possible application of nanorobots .Nanorobots might be used to seek and break kidney stones.Another important possible feature of medical nanorobots will be the capability to locate atherosclerotic lesions in stenosed blood vessels, particularly in the coronary circulation, and treat them either mechanically, chemically or pharmacologically. Christo Ananth et al. [1] proposed a method in which the minimization is per-formed in a sequential manner by the fusion move algorithm that uses the QPBO min-cut algorithm. Multi-shape GCs are proven to be more beneficial than single-shape

GCs. Hence, the segmentation methods are validated by calculating statistical measures. The false positive (FP) is reduced and sensitivity and specificity improved by multiple MTANN. Christo Ananth et al. [2] proposed a system, this system has concentrated on finding a fast and interactive segmentation method for liver and tumor segmentation. In the pre-processing stage, Mean shift filter is applied to CT image process and statistical thresholding method is applied for reducing processing area with improving detections rate. In the Second stage, the liver region has been segmented using the algorithm of the proposed method. Next, the tumor region has been segmented using Geodesic Graph cut method. Results show that the proposed method is less prone to shortcutting than typical graph cut methods while being less sensitive to seed placement and better at edge localization than geodesic methods.

This leads to increased segmentation accuracy and reduced effort on the part of the user. Finally Segmented Liver and Tumor Regions were shown from the abdominal Computed Tomographic image. Christo Ananth et al. [3] proposed a system, in which a predicate is defined for measuring the evidence for a boundary between two regions using Geodesic Graph-based representation of the image. The algorithm is applied to image segmentation using two different kinds of local neighborhoods in constructing the graph. Liver and hepatic tumor segmentation can be automatically processed by the Geodesic graph-cut based method. This system has concentrated on finding a fast and interactive segmentation method for liver and tumor segmentation. In the preprocessing stage, the CT image process is carried over with mean shift filter and statistical thresholding method for reducing processing area with improving detections rate. Second stage is liver segmentation; the liver region has been segmented using the algorithm of the proposed method. The next stage tumor segmentation also followed the same steps.

Finally the liver and tumor regions are separately segmented from the computer tomography image. Christo Ananth et al. [4] proposed a system in which the cross-diamond search algorithm employs two diamond search patterns (a large and small) and a halfway-stop technique. It finds small motion vectors with fewer search points than the DS algorithm while maintaining similar or even better search quality. The efficient Three Step Search (E3SS) algorithm requires less computation and performs better in terms of PSNR. Modified objected block-base vector search algorithm (MOBS) fully utilizes the correlations existing in motion vectors to reduce the computations. Fast Objected - Base Efficient (FOBE) Three Step Search algorithm combines E3SS and MOBS. By combining these two existing algorithms CDS and MOBS, a new algorithm is proposed with reduced computational complexity without degradation in quality. Christo Ananth et al. [5] proposed a system in which this study presented the implementation of two fully automatic liver and tumors segmentation techniques and their comparative assessment. The described adaptive initialization method enabled fully automatic liver surface segmentation with both GVF active contour and graph-cut techniques, demonstrating the feasibility of two different approaches. The comparative assessment showed that the graph-cut method provided superior results in terms of accuracy and did not present the described main limitations related to the GVF method. The proposed image processing method will improve computerized CT-based 3-D visualizations enabling noninvasive diagnosis of hepatic tumors. The described imaging approach might be valuable also for monitoring of postoperative outcomes through CT-volumetric assessments.

Processing time is an important feature for any computer-aided diagnosis system, especially in the intra-operative phase. Christo Ananth et al. [6] proposed a system in which an automatic anatomy segmentation method is proposed which effectively combines the Active Appearance Model, Live Wire and Graph Cut (ALG) ideas to exploit their complementary strengths. It consists of three main parts: model building, initialization, and delineation. For the initialization (recognition) part, a pseudo strategy is employed and the organs are segmented slice by slice via the OAAM (Oriented Active Appearance method). The purpose of initialization is to provide rough object localization and shape constraints for a latter GC method, which will produce refined delineation. It is better to have a fast and robust method than a slow and more accurate technique for initialization. Christo Ananth et al. [7] proposed a system which uses intermediate features of maximum overlap wavelet transform (IMOWT) as a pre-processing step. The coefficients derived from IMOWT are subjected to 2D histogram Grouping. This method is simple, fast and unsupervised. 2D histograms are used to obtain Grouping of color image. This Grouping output gives three segmentation maps which are fused together to get the final segmented output. This method produces good segmentation results when compared to the direct application of 2D Histogram Grouping.

IMOWT is the efficient transform in which a set of wavelet features of the same size of various levels of resolutions and different local window sizes for different levels are used. IMOWT is efficient because of its time effectiveness, flexibility and translation invariance which are useful for good segmentation results. Christo Ananth et al. [8] proposed a system in which OWT extracts wavelet features which give a good separation of different patterns. Moreover the proposed algorithm uses morphological operators for effective segmentation. From the qualitative and quantitative results, it is concluded that our proposed method has improved segmentation quality and it is reliable, fast and can be used with reduced computational complexity than direct applications of Histogram Clustering. The main advantage of this method is the use of single parameter and also very faster. While comparing with five color spaces, segmentation scheme produces results noticeably better in RGB color space compared to all other color spaces. Christo Ananth et al. [9] presented an automatic segmentation method which effectively combines Active Contour Model, Live Wire method and Graph Cut approach (CLG). The aim of Live wire method is to provide control to the user on segmentation process during execution. Active Contour Model provides a statistical model of object shape and appearance to a new image which are built during a training phase. In the graph cut technique, each pixel is represented as a node and the distance between those nodes is represented as edges. In graph theory, a cut is a partition of the nodes that divides the graph into two disjoint subsets. For initialization, a pseudo strategy is employed and the organs are segmented slice by slice through the OACAM (Oriented Active Contour Appearance Model). Initialization provides rough object localization and shape constraints which produce refined delineation.

This method is tested with different set of images including CT and MR images especially 3D images and produced perfect segmentation results. Christo Ananth et al. [10] proposed a work, in this work, a framework of feature distribution scheme is proposed for object matching. In this approach, information is distributed in such a way that each individual node maintains only a small amount of information about the objects seen by the network. Nevertheless, this amount is sufficient to efficiently route queries through the network without any degradation of the matching performance. Digital image processing approaches have been investigated to reconstruct a high resolution image from aliased low resolution images. The accurate registrations between low resolution images are very important to the reconstruction of a high resolution image. The proposed feature distribution scheme results in far lower network traffic load.

To achieve the maximum performance as with the full distribution of feature vectors, a set of requirements regarding abstraction, storage space, similarity metric and convergence has been proposed to implement this work in C++ and QT. Christo Ananth et al. [11] discussed about an important work which presents a metal detecting robot using RF communication with wireless audio and video transmission and it is designed and implemented with Atmel 89C51 MCU in embedded system domain. The robot is moved in particular direction using switches and the images are captured along with the audio and images are watched on the television .Experimental work has been carried out carefully. The result shows that higher efficiency is indeed achieved using the embedded system. The proposed method is verified to be highly beneficial for the security purpose and industrial purpose. The mine sensor worked at a constant speed without any problem despite its extension, meeting the specification required for the mine detection sensor. It contributed to the improvement of detection rate, while enhancing the operability as evidenced by completion of all the detection work as scheduled. The tests demonstrated that the robot would not pose any performance problem for installation of the mine detection sensor. On the other hand, however, the tests also clearly indicated areas where improvement, modification, specification change and additional features to the robot are required to serve better for the intended purpose. Valuable data and hints were obtained in connection with such issues as control method with the mine detection robot tilted, merits and drawbacks of mounting the sensor, cost, handling the cable between the robot and support vehicle, maintainability, serviceability and easiness of adjustments.

These issues became identified as a result of our engineers conducting both the domestic tests and the overseas tests by themselves, and in this respect the findings were all the more practical. Christo Ananth et al. [12] discussed about Vision based Path Planning and Tracking control using Mobile Robot. This paper proposes a novel methodology for autonomous mobile robot navigation utilizing the concept of tracking control. Vision-based path planning and subsequent tracking are performed by utilizing proposed stable adaptive state feedback fuzzy tracking controllers designed using the Lyapunov theory and particle-swarm-optimization (PSO)-based hybrid approaches. The objective is to design two self-adaptive fuzzy controllers, for x-direction and y-direction movements, optimizing both its structures and free parameters, such that the designed controllers can guarantee desired stability and, simultaneously, can provide satisfactory tracking performance for the vision-based navigation of mobile robot.

The design methodology for the controllers simultaneously utilizes the global search capability of PSO and Lyapunovtheory-based local search method, thus providing a high degree of automation. Two different variants of hybrid approaches have been employed in this work. The proposed schemes have been implemented in both simulation and experimentations with a real robot, and the results demonstrate the usefulness of the proposed concept. Christo Ananth et al. [13] discussed about a model, a new model is designed for boundary detection and applied it to object segmentation problem in medical images. Our edge following technique incorporates a vector image model and the edge map information. The proposed technique was applied to detect the object boundaries in several types of noisy images where the ill-defined edges were encountered. The proposed techniques performances on object segmentation and computation time were evaluated by comparing with the popular methods, i.e., the ACM, GVF snake models. Several synthetic noisy images were created and tested.

The method is successfully tested in different types of medical images including aortas in cardiovascular MR images, and heart in CT images. Christo Ananth et al. [14] discussed about the issue of intuitive frontal area/foundation division in still pictures is of awesome down to earth significance in picture altering. They maintain a strategic distance from the limit length predisposition of chart cut strategies and results in expanded affectability to seed situation. Another proposed technique for completely programmed handling structures is given taking into account Graph-cut and Geodesic Graph cut calculations. This paper addresses the issue of dividing liver and tumor locales from the stomach CT pictures. The absence of edge displaying in geodesic or comparable methodologies confines their capacity to exactly restrict object limits, something at which chart cut strategies by and large exceed expectations. A predicate is characterized for measuring the confirmation for a limit between two locales utilizing Geodesic Graph-based representation of the picture. The calculation is connected to picture division utilizing two various types of nearby neighborhoods in building the chart. Liver and hepatic tumor division can be naturally prepared by the Geodesic chart cut based strategy. This framework has focused on finding a quick and intuitive division strategy for liver and tumor division.

In the pre-handling stage, Mean movement channel is connected to CT picture process and factual thresholding technique is connected for diminishing preparing zone with enhancing discoveries rate. In the Second stage, the liver area has been divided utilizing the calculation of the proposed strategy. Next, the tumor district has been portioned utilizing Geodesic Graph cut strategy. Results demonstrate that the proposed strategy is less inclined to shortcutting than run of the mill diagram cut techniques while being less delicate to seed position and preferable at edge restriction over geodesic strategies. This prompts expanded division exactness and decreased exertion with respect to the client. At long last Segmented Liver and Tumor Regions were appeared from the stomach Computed Tomographic picture. Christo Ananth et al. [15] discussed about efficient content-based medical image retrieval, dignified according to the Patterns for Next generation Database systems (PANDA) framework for pattern representation and management. The proposed scheme use 2-D Wavelet Transform that involves block-based low-level feature extraction from images. An expectation–maximization algorithm is used to cluster the feature space to form higher level, semantically meaningful patterns. Then, the 2-component property of PANDA is exploited: the similarity between two clusters is estimated as a function of the similarity of both their structures and the measure components. Experiments were performed on a large set of reference radiographic images, using different kinds of features to encode the low-level image content. Through this experimentation, it is shown that the proposed scheme can be efficiently and effectively applied for medical image retrieval from large databases, providing unsupervised semantic interpretation of the results, which can be further extended by knowledge representation methodologies.

Biomedical Flows

The bloodstream keeps the human body alive. In the blood, suspended in the plasma, is found the white blood cells, red blood cells, and platelets. The plasma represents 55% of the blood volume which is 8% of the body weight, with the size of red blood cells is about 7.5 µm in diameter and 2 µm thick. Platelets are 2 to 4 µm in diameter.The heart keeps theclosed circulatory system working continuously. The bloodstream flows with the pumping system comprised of a closed system of blood vessels. For mammals and human,this system is basically comprised of 2 pumps dynamically synchronized. The heart performs a key role for the human wellbeing, delivering O2 to large range of tissues, whichreturns CO2 to the lungs. The blood is pumped from the left ventricle through the arteries and arterioles to the capillaries (fig. 1).

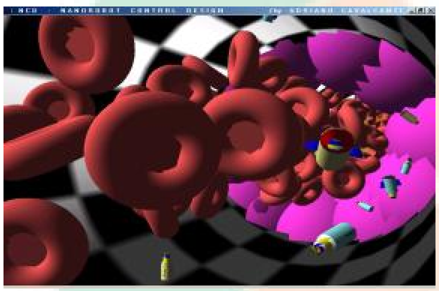

Figure 2: View of the NCD simulator workspace showing the inside view of the occluded LAD coronary artery, red blood cells and nanorobots.

After that, the blood flows from venules into the veins back to the right atrium completing the systemic circulation. In the right atrium the blood is pumped through the lungs. The lungs equilibrate the O2 and CO2 in the alveolar air . Although the bloodstream presents in most cases laminar flow, in the heart we have turbulent flow. The sounds produced by the heart are the result of diastolic and systolic pressures, which comes from the partially constricted vibrating arteries motions. Blood waveforms can also be analysed using Fourier models to quantify the dynamics of blood pressure and flow. The fluid in the Left Anterior Descending (LAD) moves with velocity ~38cm/sec (fig. 2), as is typical of flow in aorta and arteries vessels.However, the velocity under certain circumstances can even achieve up to 120cm/sec during a systolic phase. The distances are large compared to the water molecules, and then physical processes in the turbulent flow are based on the Navier-Stokes and other continuum equations.The fluid is incompressible. Thus, the fluid velocity v satisfies the continuity equation $\nabla \cdot v = 0$ and the Navier-Stokes equation:

$$\frac{\partial v}{\partial t} + (v \cdot \nabla) v = f - \frac{1}{\rho} \nabla P + \frac{\eta}{\rho} \nabla^2 v$$

where η is the fluid's viscosity, r its density, P is the pressure and f is the external force, per unit mass, imposed on the fluid.The Reynolds number, defined as

$$\mathrm{Re} = L \rho v / \eta$$

for objects of size L with velocity v, characterizes this behavior by giving the ratio of inertial to viscous forces. For nanoscale robots operating in fluids of ordinary viscosities, Re is low of around 500 . As an example, water has density of 1 g/cm3 and viscosity of 1 centipoise, or 10-2 g/cm-sec. Thus a nanorobot of size 1mm moving at 1 mm/sec in water has Re=10-3, much less than 1 and hence viscous forces dominate. As boundary conditions, the fluid velocity v matches the velocity of each object in the fluid at the object's surface. We also impose a constant input velocity along the pipe as a boundary condition to maintain the fluid flow. In practice, such a condition would be maintained by a pressure gradient imposed on the fluid.

Manufacturing Technology

A nanorobot must be equipped with the necessary devices for monitoring the most important aspects of its operational workspace. Depending on the case, different gradients on temperature, concentration of chemicals in the bloodstream, and electromagnetic signature, are some of relevant parameters when monitoring patients. Teams of nanorobots may cooperate to perform predefined complex tasks on medical procedures. For such aims, computing processing, energy supply, and data transmission capabilities can be addressed through embedded integrated circuits, using advances on technologies derived from VLSI design . CMOS VLSI design using deep ultraviolet lithography provides high precision and a commercial way for manufacturing nanodevices and nanoelectronics. The CMOS industry may thrive successfully the pathway in the assembly process of manufacturing nanorobots, where the jointly use of nanophotonic and nanotubes may even accelerate further the actual levels of resolution ranging from 248nm to 157nm devices . To validate designs and to achieve a successful implementation, the use of VHDL has become the most commonmethodology utilized in the industry of integrated circuits.

Temperature Sensor

Integrated nanothermoelectric sensors could be implemented as CMOS devices with promising uses for pattern identification Such approach may permit a large production of infrared thermal sensors applied into different ranges of wavelength . Nanorobots using temperature sensors open new medical possibilities for clinical diagnosis, as well as for ubiquitous data collection, with pervasive patient monitoring. CMOS as a thermoelectric sensor has advantage of linear self-generated response with system integration without requiring bias or temperature stabilization. Thus the infrared array could be integrated on a single chip within amplifiers and signal processing capabilities. Such approach allows a fast pace towards miniaturization with no loss of efficiency due electromagnetic noise. CMOS could be operated at very low voltage levels, which is also a positive aspect, presenting good functionality and requiring little energy for nanorobots. Cantilever and bridge types are also valid techniques for possible different ways to implement CMOS thermoelectric sensors. Nanowires are suitable for fabricating CMOS based on integrated nanodevices.Carbon nanotubes are able to improve performance with low power consumption for nanosensors.Its particular high precision make it quite useful for applications in infrared supersensitive sensors, with applications such as target oriented temperature detection,and measurement in changes of the body temperature.Nanosensors present important electrical properties, high thermal conductance and fast frequency response.The power consumption with NEMS is three times lower if compared with traditional MEMS thermal sensors, where for MEMS the operating values range in terms of mW. Nanowires can be configured as two-terminal devices electrically designed to work as high or low resistance diodes. Crossed nanowire p-n junctions can function successfully as logic gates from crossed nanowire field-effect transistors. Therefore, microwire pitch incorporated in actual CMOS integrated designs can be reduced to the nanowire pitch by using on-off masks aligned diagonally to produce a one-to-one microwire to nanowire correspondence.

Chemical Sensor

Application ranges from biomedical uses, automotive or chemical industry with detection of air to liquid element patterns recognition through embedded software programming. Through the use of nanowire significant costs of energy demand for data transferring and circuit operation can decrease around 60%. CMOS sensors using nanowires as material for circuit assembly can achieve maximal efficiency for applications regarding chemical changes, enabling medical applications.Due resistivity characteristics, nanocrystallites and mesoscopic nanowires performance is impressive if compared with larger sensors enabled technologies. Sensors with suspended arrays of nanowires assembled into silicon circuits can drastically decrease self-heating and thermal coupling for CMOS functionality. Nanometer chemical sensors using integrated circuits may generate huge profits with low cost for massively production of commercially devices with a wide range of applications in medical, industrial, environmental issues, and much more. Factors like low energy consumption and high-sensitivity are among some of advantages of nanosensors. Nanosensor manufacturing array process can uses electrofluidic alignment to achieve integrated CMOS circuit assembly as multi-element . Passive and buried electrodes should be used to enable cross-section drive transistors for signal processing circuitry readout. The passive and buried aligned electrodes must be electrically isolated to avoid loss of processed signals. Control feedback to switch the electronic sensor between active or turned off sensing are quite indicated for nanorobot medical monitoring operations. The use of nanowire for integrated sensors is to achieve new breakthroughs in high speed sensing and control technologies. For chemical sensor device the range for the CMOS operation is ~190MHz. Control of data transmission is the most suitable path for save the nanorobot's energy when the sensor is in operation, thus sample techniques can be used with time interval of 80 ns for active circumstances. Some of limitations to improve actual CMOS and MOSFET methodologies are quantum-mechanical tunnelling for operation of thin oxide gates, and subthreshold slope. Surpassing any expectations the semiconductor branch has moved forward to keep circuit advancing. Smaller channel length and lower voltage circuitry for higher performance are being achieved with new materials aimed to attend the growing demand of high complex VLSIs. New materials such as strained channel with relaxed

SiGe layer are quoted to beat self-heating and improve performance. Recent developments on 3D circuits and FinFETs double-gates have achieved astonishing results and according to the semiconductor roadmap should improve even more. To advance further manufacturing techniques, Silicon-On-Insulator (SOI) technology has been used for assembly high performance logic sub 90nm circuits. Circuit design approaches to solve problems with bipolar effect and hysteretic variations based on SOI structures has been demonstrated successfully. Altogether, it is turning feasible 90nm and 45nm CMOS devices as an actual breakthrough in terms of technology devices into products that can be utilized strategically.

Energy Supply

The most effective way to keep the nanorobot operating continuously is to establish the use of power generated from the available sources in the environment where it must be working. Some possibilities to power it can be provided from ambient energy. Kinetic energy can be generated from bloodstream due motion interaction with designed devices embedded outside the nanorobot. Electromagnetic radiation from light could be another option for energy generation in open workspaces , but not for medical nanorobotics. Temperature displacements could likewise generate radiation developing pre-established voltages. Cold and hot fields from in series connected conductors may also be useful to produce energy through the well-established Seebeck effect . Temperature changes or light variations for different kinds of workspace could sharply variates depending on the application. Here, specifically on the aspect light, it does not exist inside the human body. Thus, considering a broader design choice, the energy generated by kinetic vibration is more appropriated. It is more suitable for a larger variety of applications for biomedical problems or even environmental monitoring. A device for power generation using integrated circuits allied with Li-ion batteries is a good choice to provide electrical sources for the nanorobot operation. A system with resonance frequency as μPG (micro power generator) is suitable for power supply. Bloodstream flow vibrations once captured is translated with piezoelectricity, into energy source for the nanorobot operation. Due operational aspects such as integration and power density, it is a more efficient approach than electrostatic or electromagnetic induction . The energy generated is saved in ranges of ~1μW while the nanorobot can stay in inactive modus, just becoming active when signal patterns requires so. Allied with the power source devices, in order to save energy using such resource wisely, the nanorobots need to perform strategically defined actions in the workspace. Therefore the team of nanorobots can be prepared to acquire and transmit more or less information depending on changes in determined medical target. Some of the typical tasks may require the nanorobot to spend low power amounts, once strategically activated. For communication sending RF signals

~1mW is required. The collected data can be expressed in bits pattern signals, what permits to keep the power consumption with data transmission low.

Data Transmission

The application of devices and sensor implanted inside the human body to transmit data about the health of patients can enable great advantages on continuous medical monitoring.For communication in liquid workspaces, depending on the application, it is worth to quote acoustic, light, RF, and chemical signals as possible choices for communication and data transmission.Chemical signal is quite useful for nearby communication among nanorobots for some teamwork coordination .Acoustic communication by other hand is more appropriated for long distance communication and detection with low energy consumption if compared to light communication approaches. Although optical communication permits faster rates of data transmission, its energy demand makes it not ideal for nanorobots.Works with RFID (Radio Frequency Identification Device) has been developed as integrated circuit for medicine. Prevision of low cost polymer electronics for tiny magnetic sensors and transducers chips are expected to achieve low costs as 1 cent for circuit, what makes its use even more attractive . Using integrated sensors for data transfer is the better answer to read and write data in implanted devices. The teams of nanorobots should be equipped with single-chip RFID CMOS based sensors. CMOS with submicron SoC design could be used for extremely low power consumption with nanorobots communicating actively for some bit longer distances through sonar sensors. For the nanorobot active sonar communication, frequencies may reach up to 20µW@8Hz as resonance rates and 3V supply. Thus, strategically positioned static sensors for acquiring wireless data transmission from mobile nanorobots injected inside the patient bodies comprise a good choice to monitoring predefined patterns for biomedical applications. To accomplish that, acoustic nanosensors may be exchanging communication, and strategic data information should be transmitted when some new event was registered from nanorobots as mobile device inside the patient's body. In our design, an electromagnetic reader is applied to launch waves and detect the current status of nanorobots inside the patient. This transponder device emits magnetic signature to the passive CMOS sensors embedded in the nanorobot, which enable sending and receiving data through electromagnetic fields. The nanorobots monitoring data convert the wave propagation generated by the emitting devices through a well defined protocol. According with a last set of event recorded in pattern arrays, information can be reflected back by wave resonance . For nanorobot passive data transferring, possible ranges for data communication are ~4.5 kHz frequency with approximate 22 µs delays. While for receiving data from the nanorobots should be achieved with such passive process, sonar communication is to be used for active communication among nanorobots to perform coordinated behaviors due some more complex collective task to be fulfilled.

System Implementation

The simulation consists of adopting a multi-scale view of the environment. It has the physical morphology with physiological flow patterns, this allied with the nanorobot orientation, drive mechanisms, sensing and control. Thus,
these simulations are used to achieve high-fidelity control modeling of nanorobots in a real physical context. The simulation includes: the NCD (Nanorobot Control Design) simulator for the nanorobot sensing and actuation; and CFD (Computational Fluid Dynamics) software for the patient parameters.

Nanorobot Design

The nanorobot design is comprised of integrated nanoelectronics and components such as molecular sorting rotors and a robot arm (telescoping manipulator) , derived from biological models. The nanorobot exterior shape consists of a diamondoid material, to which may be attached an artificial glycocalyx surface that minimizes fibrinogen (and other blood proteins) adsorption and bioactivity, ensuring sufficient biocompatibility to avoid immune system attack. Different molecule types are distinguished by a series of chemotactic sensors whose binding sites have a different affinity for each kind of molecule. These sensors also detect obstacles which might require a new trajectory planning.We simulate the nanorobot with sensory capabilities allowing it to detect and identify the nearby possible obstacles in its environment, as well as the biomedical target for its task. A variety of sensors are possible . For instance, chemical detection can be very selective, e.g., for identifying various types of cells by markers on their surfaces. Acoustic sensing is another possibility, using different frequencies to have wavelengths comparable to the object sizes of interest.Sensor design and capabilities depend on the details of the environment and task. Thus, the nanorobot requires transducers capabilities and smart sensors directly related to that specific biomedical application. In present study, the nanorobot is able to detect obstacles over a range of about 1mm, and within an angular resolution equivalent to a diameter of 100nm at that range. The biomolecules are too small to be detected reliably: instead the robot relies on chemical contact sensors to detect them. This description of interaction capabilities allows evaluating different nanorobot sensor based action. It also helps to choose the kind of low-level control to maximize the information acquired for an effective real time performance. The nanorobot kinematics can be predicted using state equations, positional constraints, inverse kinematics and dynamics, while some individual directional component performance can be simulated using control system models of transient and steady-state response. The nanorobots can use a RFID CMOS macrotransponder system for their positioning, which allow information about the nanorobot position, independent of nanorobot orientation . Such a system could involve externally generated signals from beacons placed at fixed positions outside the skin.

Modular Integration

Graphic interfaces enabling detailed design are progressing rapidly to produce 3D nano-structure prototypes. The Nanorobot Control Design (NCD) is multithread software. It is comprised of collision detection and physically based simulation .We used parallel processing techniques where the nanorobots react adaptively to any stimulus produced by their partners' decisions, with the model visualization in real time. Ongoing developments in hardware and distributed processing allow the increasing number of nanorobots and the level of detail for the simulator. Virtual reality techniques provide an intuitive way to interact with nanoscale components.The NCD simulator was used for the 3D investigation of a stenosed Left Anterior Descending (LAD) coronary artery (Fig. 1). The NCD simulator consists of several modules that simulate the physical conditions, run the nanorobot control programs determining their actions, provide a visual display of the environment in 3D, and record the history of nanorobot behaviors for later analysis.The approach used aims to trigger the process of medical molecular machine activation. This trigger will turn the nanorobot "on", switching it from "seek mode" to "repair mode". It may also cause other close nanorobots switch to a"higher awareness mode". Clinical data and diagnose gives previous knowledge about the general localization of the stenosis (in large, small or microvessels), thus it requires to inject the appropriate nanorobot type, which is preprogrammed to be activated only at the pre-specified target region. The virtual environment developed is inhabited by plasma, red blood cells, nanorobots, different molecules whose concentrations are being monitored, and the blood vessel (Fig. 2). The biomedical physical parameters were implemented with Computational Fluid Dynamics (CFD); thus, the blood flow pulse is simulated in a stenosed LAD coronary artery model, differing in the degree of stenosis severity. By solving the flow governing equations it is computed the blood velocity profiles (Fig. 3). It was also defined and calculated various signaling functions, known to be indicative of stenosis, caused by an atherosclerotic plaque. Such parameters include time-averaged wall shear stress, wall shear stress gradients and oscillatory shear index . Christo Ananth et al. [16] discussed about E-plane and H-plane waveguides (Microwave Engineering) applicable to image processing. Christo Ananth et al. [17] discussed about principles of electronic devices to explain this feature.

Simulation Discussion

Nanorobots may be considered as the most suitable tool for specialists to solve several problems in medicine in the coming few year, here including cardiology interventions and medical analyses.In our study, the nanorobot includes external sensors to inform it of collisions and to identify when it has encountered a chemical signal or abrupt changes of temperature for targeted areas. As a practical approach for medicine, thermal and chemical parameters from the patient's body are used for the nanorobot activation.Hence, in order to simulate various levels of inflammation, it was used different wall temperatures in the atherosclerotic plaque region, and calculated the temperature distribution in the stenosed coronary artery. Significant temperature gradients were found in the recirculation zone, following the stenosis.The transcardiac concentration gradient of some soluble adhesion molecules has been recently found to be correlative with the progression of coronary atherosclerosis . Therefore, their concentration in the blood vessel is alsomonitored, using a uniform distribution release from the plaque. In a similar manner, the concentrations of some specific pro-inflammatory cytokines is monitored, whose elevated concentrations are known as an evidence of formation of atherosclerotic lesions. Christo Ananth et al. [18] gave a brief outline on Electronic devices and circuits which is the basis for formation of patterns.

The parameters generated from the CFD simulation, namely velocities,

Figure 6: Vein inside view without the red blood cells. The target plaque is represented by the pink spheres surrounding the vessel wall. The nanorobots swim in a near-wall region searching for theatherosclerotic lesion

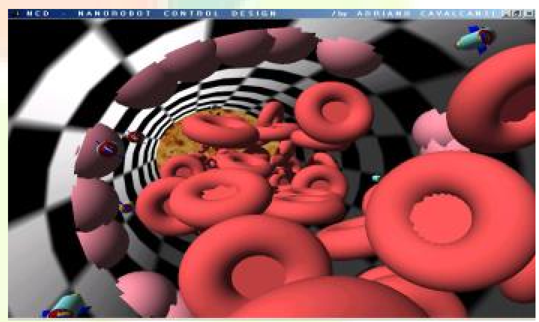

Figure 7: The atherosclerotic lesion was reduced due nanorobots activation. The temperatures in the region turn in expected levels.

temperature, signaling values, pro-inflammatory cytokines and soluble adhesion molecules concentrations, are transferred to the NCD simulator to be included into the nanorobots operating environment. As the nanorobot should perform a pre-defined task in a specific target area, the trigger must be activated when the nanorobot is as close as possible to the target. The nanorobot motion control in the artery keeps it near-wall region. It takes the advantage of the blood flow velocity profile in such areas, which shows significantly lower velocities. Thus, the rapid activation could result in lower demand of energy (Fig. 6). Optimization of control algorithms and activating triggers is the key for rapid behavior response in minimal energy cost. The optimal trigger values are defined running the nanorobots control programs. Therefore, the investigated stenosed artery models provide important information useful to nanorobot manufacturing design in terms of sensors and actuators. The nanorobots activation goal is to decrease the artery occlusion (Fig. 7).

Conclusion

A study with the ways to establish a trigger and control behavior for nanorobots in cardiology was adopted as medical case in our work. The use of thermal and chemical parameters applied in the treatment of stenosed blood vessels is the most natural process for nanorobot transducer effective development. The approach presented in this paper, has successfully combined a precise physical simulation to establish the environment for operation of nanorobots. A system to study nanorobots behavior is described, and the ways to achieve their control inside the human body is also presented. The NCD and CFD have demonstrated extreme potential for scientific investigation of nanomanufacturing strategies, medical nanorobotics application, and nanorobot mobility considerations. The jointly use of nanophotonic and nanotubes may even accelerate further the actual levels of CMOS resolution ranging from 45nm devices. The aim in this study was to show an innovative framework for enabling designs and models of medical nanorobots. Meanwhile nanoelectronics manufacturing methodologies may advance progressively, the use of computational nanomechatronics and virtual reality may also help in the process of transducers and actuators investigation. Thus, our study points towards possible ways to advance nanotechnology as diagnostic and treatment tool using nanorobots for cardiology patients.

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