A System for Data Communication for Nanorobots in a Laser-Free Nanorobotic Surgery Instrument for the Retina

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Abstract: - Designing a laser-free surgical nanorobotic instrument for the retina involves creating a system capable of operating at micrometric or nanometric scales, aiming to perform precise and efficient interventions such as medication or surgery on the retina. This article presents the data communication system between nanorobots and the surgeons team will be part of developing a system that enables efficient data communication and control of the retina operating instrument and other medical equipment.

Key-Words: - surgical nanorobotics, retina operating instrument, communication system, swarm of nanorobots, Secure Communications, data encryption

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1 Introduction

1.1 Generalities on the retina operating (by medication or surgery) semi-automated instrument

The retina is an extremely sensitive and complex tissue, and medication and/or surgical treatments at this level require very precise interventions. Nanotechnology offers the possibility of developing tools that can operate at the level of individual cells or microscopic structures, so that they can perform minimally invasive surgeries, reducing risks and recovery time.

A laser-free nanorobotic surgical tool for the retina will be based on high-precision technologies, replacing laser technology with precise control nano mechanisms.

1.2 Communication Systems proposed to be used for nanorobots

Medical robotics does not replace the doctors, it helps them to perform the treatment in certain cases. A nanorobot does not exceed micrometers and usually has 1-100 nm.

These small robotic components may be components of the micro-surgical instrument. Nanomedicine is a interdisciplinary science, namely physics, biology, chemistry, optics, medicine, and engineering for diagnosis and treatment of human body diseases at micro/nano dimensional levels down to 1-100 nm, using micro/nanotechnologies.

Nanorobots need to communicate with each other and with doctors team, and also with a central system to coordinate activities and transmit data. In a swarm system (robots in a group), they must cooperate to perform a complex task. Communication options may include:

• Optical communication: Nanorobots can use light to transmit data. This system could use photons to carry information between nanorobots.

• Radio wave communication (cognitive radio): Cognitive radio technology allows dynamic allocation of frequency spectrum, optimizing communications between nanorobots to reduce interference.

• Elliptic curve communication for encrypting data transmitted between nanorobots. Elliptic curve-based encryption is effective for secure communications, ensuring data confidentiality and integrity.

The nanorobot will be controlled through an advanced telecommunication system, which may include:

• Wireless control: Using low-power radio frequencies, the surgeon can send commands to the nanorobot.

• Control interface: The control systems will include a central unit that receives input from the surgeon and translates these commands into signals for the nanorobot.

• Sensory feedback: The nanorobot will be equipped with sensors that transmit feedback about its position, the force applied to the tissue, or the overall condition of the retina, thus providing the surgeon with real-time information.

More nanorobots will act together in a swarm to perform the retina drug delivery or surgery.

A swarm of biochemical nanorobots is the proposed group of nanorobots that collaborate and communicate with each other to perform complex tasks efficiently and in a coordinated manner. This concept is based on the emergent behavior of a large number of autonomous entities interacting to achieve a collective action, similar to how social insects, such as bees or ants, work together. In the context of retinal surgery, such a biochemical swarm of nanorobots could be used to detect, treat, and monitor retinal conditions with high precision and wider coverage of the affected tissues.

Securing this communication is accomplished through encryption, authentication, and signal protection. This approach will allow precise coordination of the nanorobots during treatments and will contribute to the success of the surgical procedure.

Cognitive Radio represents an innovative concept in the field of nanorobots communications, which integrates cognitive radio principles (a type of adaptive wireless communication technology) with biochemical processes to create a system capable of adapting and optimizing communication based on the chemical conditions of the biological environment.

In this context, cognitive radio (CR) refers to a communication system that can detect and understand environmental conditions and adjust its communication parameters to optimize network performance.

2 Communication Between Nanorobots

2.1 Communication Between Nanorobots in a Swarm

A swarm of nanorobots involves a network of nanorobots that communicate with each other and coordinate their actions to achieve common goals. In this context, communication between nanorobots must be extremely fast, reliable, and able to operate in a complex physiological environment, such as the human eye.

2.2 Cognitive Radio used for Data Communications between nanorobots and with the surgeons team.

Cognitive Radio is a communication technology that allows networks to use the available frequency spectrum dynamically, relying on radio environment analysis (spectrum sensing) to detect free channels and use them without interfering with other signals. We will simulate the operation of such a system, with the aim of implementing a network of nanorobots that communicate with each other using the dynamically available radio spectrum.

2.3 Simulation of data communication between nanorobots and with the surgeons team

Creating a complex project such as an autonomous nanorobotic system for retinal surgery requires a wide range of programs to simulate and control the various components of the system: from nanorobot navigation to communication between them and optical image processing.

In this section, we will describe the structure of the programs used for each part of this component, using various programming languages and simulation platforms, including software for nanorobot data communication.

2.4 Communication Program Between Nanorobots. An example.

This program simulates the transmission of Cognitive Radio signals between nanorobots to enable information exchange.

We will use a simple protocol for multiplexing signals at different frequencies to avoid interference between the robots. Here is an example:

RESULT

Robot 1 transmits: Operation in progress at a frequency of 2 Hz

Robot 2 received the signal: Robot 1 transmits: Operation in progress at a frequency of 2 Hz

Robot 3 received the signal: Robot 1 transmits: Operation in progress at a frequency of 2 Hz

Robot 4 received the signal: Robot 1 transmits: Operation in progress at a frequency of 2 Hz

Robot 5 received the signal: Robot 1 transmits: Operation in progress at a frequency of 2 Hz

Robot 2 transmits: Operation in progress at a frequency of 5 Hz

Robot 1 received the signal: Robot 2 transmits: Operation in progress at a frequency of 5 Hz

Robot 3 received the signal: Robot 2 transmits: Operation in progress at a frequency of 5 Hz

Robot 4 received the signal: Robot 2 transmits: Operation in progress at a frequency of 5 Hz

Robot 5 received the signal: Robot 2 transmits: Operation in progress at a frequency of 5 Hz

Robot 3 transmits: Operation in progress at a frequency of 10 Hz

Robot 1 received the signal: Robot 3 transmits: Operation in progress at a frequency of 10 Hz

Robot 2 received the signal: Robot 3 transmitting: Operation in progress at 10 Hz

Robot 4 received the signal: Robot 3 transmitting: Operation in progress at 10 Hz

Robot 5 received the signal: Robot 3 transmitting: Operation in progress at 10 Hz

Robot 4 transmitting: Operation in progress at 10 Hz

Robot 1 received the signal: Robot 4 transmitting: Operation in progress at 10 Hz

Robot 2 received the signal: Robot 4 transmitting: Operation in progress at 10 Hz

Robot 3 received the signal: Robot 4 transmitting: Operation in progress at 10 Hz

Robot 5 received the signal: Robot 4 transmitting: Operation in progress at 10 Hz

Robot 5 transmitting: Operation in progress at 5 Hz

Robot 1 received the signal: Robot 5 transmitting: Operation in progress at 5 Hz

Robot 2 received the signal: Robot 5 transmitting: Operation in progress at 5 Hz

Robot 3 received the signal: Robot 5 transmitting: Operation in progress at 5 hz

Robot 4 received the signal: Robot 5 transmitting: Operation in progress at frequency 5 Hz

2.5 Cognitive Radio used for Data Transmission

We propose a simplified radio spectrum sensing system that allows a group of nanorobots to detect available channels and communicate through them without interfering with other signals.

Here is a simulation result:

Channel 4 is free and will be used.

The 'Important Message' data has been transmitted through channel 4.

Channel 4 is free and will be used.

The 'Important Message' data has been transmitted through channel 4.

Channel 3 is free and will be used.

The 'Important Message' data has been transmitted through channel 3.

Channel 2 is free and will be used.

The 'Important Message' data has been transmitted through channel 2.

Channel 2 is free and will be used.

The 'Important Message' data has been transmitted through channel 2.

Channel 4 is free and will be used.

The 'Important Message' data has been transmitted through channel 4.

Channel 2 is free and will be used.

The 'Important Message' data has been transmitted through channel 2.

Channel 2 is free and will be used.

The 'Important Message' data has been transmitted through channel 2.

Channel 1 is free and will be used.

The 'Important Message' data has been transmitted through channel 1.

Channel 1 is free and will be used.

The 'Important Message' data has been transmitted through channel 1.

In this simulation program, Cognitive Radio simulates the detection of free channels and data transmission using an available channel. Each nanorobot will detect a free channel and transmit its data using Cognitive Radio technology.

2.6 Data encryption

2.6.1 Galois Encryption and Elliptic Curves for Secure Communications

Galois encryption and elliptic curves are advanced cryptographic techniques that can be used to ensure secure communications between nanorobots.

In this context, encryption is based on polynomial equations over finite fields, and elliptic curves provide an efficient algorithm for encryption and digital signatures.

3 Detailed Implementation Programs for data encryption

3.1 Galois Encryption

Galois encryption over finite fields is uses encryption based on the algebraic properties of finite fields to secure data transmission. Finite fields, known as Galois fields, are algebraic structures consisting of a finite set of elements, with addition and multiplication operations. These fields are used in cryptographic protocols, such as the Advanced Encryption Standard (AES), Elliptic Curve Cryptography (ECC), and error-correcting codes. The use of finite fields in cryptography is based on their deterministic and complex behavior under arithmetic operations, which gives as results efficient computation, error detection, and secure communication protocols. Galois encryption over finite fields is based on polynomials and modular arithmetic. The program will implement the encryption and decryption of a message, using a low-degree polynomial.

Example 1

Result

Encrypted message: [-1, 0, 3, 0]

Decrypted message: [1, 1, -1, 1]

Example 2

Result

Encrypted text: [3], [56], [116], [95], [183], [34]
Decrypted text: Hello!

This program uses arithmetic over a finite field to encrypt and decrypt a message, using a defined polynomial. The encryption polynomial can be customized to provide additional security.

3.2 Elliptic Curves used for Digital Signature

Elliptic curves are used for generating cryptographic keys and digital signatures. We will use elliptic curves to sign and verify the signature of a message.
Example
Result
Is the signature valid? True

Here is used a symmetric signature – meaning the same key is used for signing and verification.

This program uses NIST384p elliptic curves to sign a message and to verify its signature.

In this example, each nanorobot can sign the data it sends, and the other robot can verify the signature to ensure the integrity of the data.

3.3 Data Communication System Integration for nanorobots

Together, these technologies (Galois encryption, elliptic curves, and cognitive radio) will ensure:

• Data security through encryption and digital signature.

• Efficient communication between nanorobots using Cognitive Radio technology, which allows for the optimization of frequency spectrum usage.

• Autonomy and reliability in data communication and handling, ensuring their safety and integrity.

4 Conclusion

These applications are proposed for data communication for an autonomous retinal surgery system based on nanorobots.

Each component (encryption, elliptic curves, cognitive radio) adds a layer of complexity and safety necessary to ensure that the system operates correctly, efficiently, and safely in a biological environment.

These components can be expanded to address all the requirements of a complete retinal surgery system.

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