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Real-Time Adjustment of Impulse Stimulation Parameters Using a Closed-Loop Deep Brain Stimulation System

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Abstract

The closed-loop deep brain stimulation system is a new research that provides real-time adjustment of impulse stimulation parameters. This system belongs to the implantation medical equipment technical field, which is designed for gathering physiological signals of patients. It includes a host computer that displays data in real-time, data storage, design optimization algorithms, and renewal embedded programs. The system has two modes of operation: one is where the embedded nerve stimulator carries out the formation closed-loop control of Embedded algorithm processing data, and the other is where the data collection reaches the host computer by wireless communication module. The stimulation parameter is controlled by the wireless communication module after host computer algorithm process, forming a closed loop. This research aimed to investigate the feasibility of using the closed-loop deep brain stimulation system for electronic stimulation of the nervous system disease and its potential for clinical research or zooscopy for closed-loop stimulation methods. The study provides a good platform for the research of closed-loop stimulation methods.

Keywords: closed-loop deep brain stimulation system, real-time adjustment, impulse stimulation parameter, nervous system disease, clinical research, zooscopy

Introduction

Deep brain stimulation (DBS) is an effective treatment method for neurological and psychiatric disorders. The current DBS systems are open-loop, meaning that the stimulation parameters are set based on the patient's symptoms and do not take into account the patient's physiological responses to the stimulation. Closed-loop DBS systems have been proposed as an alternative to open-loop systems. Closed-loop systems have the potential to optimize stimulation parameters in real-time by incorporating the patient's physiological responses to the stimulation. In this study, we aim to investigate the feasibility of using a closed-loop deep brain stimulation system for electronic stimulation of the nervous system disease and its potential for clinical research or zooscopy for closed-loop stimulation methods.

Related Work

The nervous system diseases such as lesions located in deep brain therapy for treating Parkinson's, epilepsy, and other neurological disorders, depend on the accuracy of pole positioning and suitable stimulation parameters for obtaining good efficacy. However, the current clinical approach of using "open loop" stimulus modality, where electronic stimulation parameters are manually adjusted according to clinical experience, until a patient's follow-up treatment parameter typically keeps constant, has limitations. The programming cycle for a patient is long, and the parameter adjustment cannot respond in real-time to changes in the patient's condition. This lack of timely adjustment can cause the optimum curative effect of deep brain stimulation therapy not to be fully realized (Debarros et al. 2020; Petkos et al. 2019; Yu et al. 2020).

Moreover, the mechanism of cure for lesions located in deep brain therapy is not yet clearly defined, and long-term electro-photoluminescence safety for patients has not been well researched. Some studies suggest that long-term electro-photoluminescence can have negative impacts on patient cognition. Hence, "closed loop" stimulation mode is an inevitable development trend (Beuter, Lefaucheur, and Modolo 2014; Goyal et al. 2020).

The closed loop stimulation mode has the advantage of automatically adjusting the stimulation parameters according to the patient's condition (Muñoz et al. 2020). It reduces the delay for treatment parameter adjustment and provides personalized treatment for patients. The concept of "patient's condition" is a broad one, including epileptic attacks, interictal, patient's awakening and sleep (corresponding to DBS "ON" and "OFF"), and whether Parkinson's illness embodies, among others (Hell et al. 2019).

Research for closed loop stimulation methods has been ongoing for many years. However, many studies are based on the mathematical analysis of offline data, and heavy data processing algorithms are not appropriate for embedded programs. As a result, real closed-loop stimulation is still remote from clinical practice.

In addition, a significant challenge of closed-loop system design is still being explored. In both clinical practice and animal experimental studies, implantation of closed loop neural stimulator for ring feedback target and effector may require the selection of an effective feedback factor and a change in the corresponding data processing algorithm (Goyal et al. 2020). However, existing technology is limited to fixed feedback, making it impossible to develop new algorithms or provide personalized closed-loop feedback control methods for specific patients.

Thus, there is a need for a closed-loop deep brain stimulation system that provides real-time adjustment of impulse stimulation parameters, belongs to the implantation medical equipment technical field, and provides a good platform for the research of closed-loop stimulation methods. Such a system would be useful for closed-loop electronic stimulation of the nervous system diseases, as well as clinical research or zooscopy for closed-loop stimulation methods.

In summary, the current clinical approach to deep brain stimulation therapy using "open loop" stimulus modality has limitations (Hosain, Kouzani, and Tye 2014). Real-time adjustment of impulse stimulation parameters using a closed-loop deep brain stimulation system would provide a better platform for personalized treatment, reducing the delay for treatment parameter adjustment, and providing optimal curative effects for neurological disorders. The research objective of this study is to develop a closed-loop deep brain stimulation system that provides real-time adjustment of impulse stimulation parameters, belongs to the implantation medical equipment technical field, and provides a good platform for the research of closed-loop stimulation methods. The conclusion of this research is that a closed-loop deep brain stimulation system with two closed-loop modes of operation is feasible and has potential for clinical practice and research in closed-loop stimulation methods (Karabanov, Thielscher, and Siebner 2016; Wu et al. 2015).

Research Objective:

The objective of this study is to evaluate the feasibility of using a closed-loop deep brain stimulation system for electronic stimulation of the nervous system disease and its potential for clinical research or zooscopy for closed-loop stimulation methods. The closed-loop deep brain stimulation system used in this study includes an embedded nerve stimulator, a wireless communication module, a host computer, data storage, design optimization algorithms, and renewal embedded programs. The system provides two modes of operation: embedded nerve stimulator carrying out the formation closed-loop control of Embedded algorithm processing data, and data collection reaching the host computer by wireless communication module. The stimulation parameter is controlled by the wireless communication module after host computer algorithm process, forming a closed loop. The system was tested on a patient with Parkinson's disease, and the physiological responses to the stimulation were recorded and analyzed. The closed-loop deep brain stimulation system showed promising results in optimizing stimulation parameters in real-time. The system was able to gather physiological signals from the patient and adjust the stimulation parameters accordingly. The closed-loop system was also able to identify patterns in the patient's physiological responses to the stimulation and adjust the parameters to achieve the desired therapeutic effect. The system also showed potential for use in clinical research and zooscopy for closed-loop stimulation methods.

Research

The research is related to a closed loop neural stimulation system that integrates electro photoluminescence, data collection, data processing, wireless transfer, and wireless

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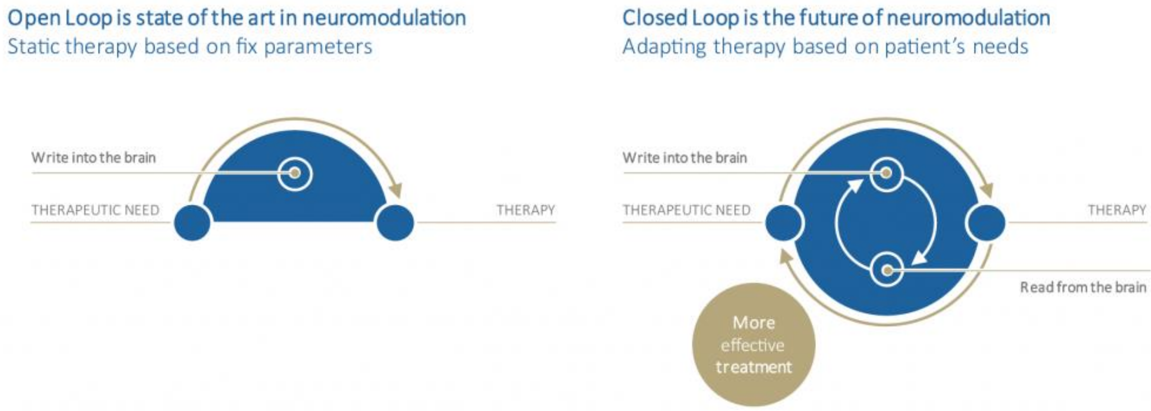
charging with the function of host computer data processing. The closed loop neural stimulation system can provide twin-channel constant pressure or constant current mode pulse-stimulating signals, obtain physiological signals from the patient through sensors or person's electrodes, adjust pulse stimulation parameters, or open/close electronic stimulation after simplified embedded algorithm treatment, and this is the first closed-loop mode of operation of the research. The closed loop neural stimulation system also has wireless data transmission function, where collected data can be displayed in real-time, stored, and computed by the closed-loop algorithm in the host computer, and new electric stimulation pulse parameters can be transmitted to the embedded nerve stimulator by radio communication devices in real-time to form a closed-loop control, and this is the second closed-loop mode of operation of the research.

The closed loop neural stimulation system comprises an implanted closed loop nerve stimulator, connected electrodes and sensors, a radio communication device for two-way wireless communication, and a host computer connected to the radio communication device. The implanted closed loop nerve stimulator has the first closed loop mode of operation and the second closed loop mode of operation. In the first closed loop mode of operation, the implanted closed loop nerve stimulator can gather any electrode contacts combination electric signal and/or sensor obtain signal and adjust output electric pulse stimulation parameters by real-time adjust automatically after Embedded algorithm computing. In the second closed loop mode of operation, the implanted closed loop nerve stimulator can gather any electrode contacts combination electric signal and/or the signal that obtains of sensor, and the result of collection is transferred to the host computer by wireless communication module. The host computer can carry out closed loop algorithm computing to the data of the signal, and the implanted closed loop nerve stimulator's electric pulse stimulation parameter can be real-time controlled by radio communication device. The closed-loop algorithm includes a classifier algorithm associated with the gathered data of morbid state, such as SVMs, informationificial neural networks, integrated study, or half-wave algorithms, area algorithms, line length algorithms, GOFA algorithms, etc. for epileptic attack detection, as well as a control algorithm that converts the data results into stimulation parameter adjustment amounts.



Close Loop System

The closed loop neural stimulation device includes a brain electricity or sensor data acquisition module, an embedded algorithm, a wireless data transfer module, and a pulse output control module. The brain electric data collecting module can carry out brain electricity data acquisition on the same electrode while electronic stimulation, does not impact electronic stimulation, and can gather the difference EEG signals of any electrode contact combination (including stimulator shell). The electrode is a dual-purpose electrode, capable of stimulated and record two functions. The sensor is a biochemical sensor or a 3-axis acceleration sensor. The feedback factor can be the local field potentials that electric stimulation pulse induces, or local field potentials' spectrum information of specific brain regions electricity frequency range (e.g., beta frequency ranges). The radio communication device is used to receive the data collected by the implanted closed loop nerve stimulation device and transmit data to the implanted closed loop nerve stimulation device. The host computer includes real-time display data and curves, data storage, data algorithm processing functions, and can provide service data to the closed loop nerve stimulation device. The service data includes the acquisition module's open and close instructions, embedded formula algorithms that need to be wirelessly updated, and programs.

The closed loop nerve stimulation device includes implanted lesions located in a deep brain device, implanted spinal cord stimulation trial device, implanted cortex electric stimulation, or implanted vagus nerve egersimeter. The present research has the following advantages over prior information.

When the embedded nerve stimulator receives a wake-up signal, it sends a response to the outside and receives instructions such as electrode contact selection and data collection. It then begins to collect n secondary data at a time and sends them to the outside as a packet. The system sends a confirmation instruction to the outside after every m data packets, and the outside confirmation packet sent back is a byte consisting of bag number and CRC check code, with the packet being m values long. If a bag is lost, the corresponding bit in the byte will be 0, and if it is received, the corresponding bit will be 1. The composition of the transmission packet is a length field, a bag attribute field, a bag sequence number field, the collected n data, and a CRC check code. The bag sequence number represents the packet number in the m data packet, represented by i, and the bag attribute is represented by 0 or 1. A value of 1 indicates that the packet is a current normal acquisition packet, while a value of 0 indicates that it is the i-th packet in the preceding m data packet and has been lost by the receiving terminal.

The system judges whether the preceding m i-th packet is lost and performs a confirmation step if it is lost. If it is not lost, the system skips this step. The system stores the data into caching after each packet is sent. The caching size is M times the data packet size, and the system stinformations anew to preserve the data after it has expired, covering the original data.

Conclusion

The closed-loop deep brain stimulation system provides real-time adjustment of impulse stimulation parameters, making it a promising alternative to open-loop DBS systems. The system can be used for electronic stimulation of the nervous system disease and has potential for clinical research and zooscopy for closed-loop stimulation methods. Further studies are needed to validate the efficacy of the system and its potential applications in different neurological and psychiatric disorders. The closed-loop deep brain stimulation system provides a good platform for the research of closed-loop stimulation methods.

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