Tomas Bata University in Zlín
Faculty of Applied Informatics

Dissertation thesis statement

Objektivizace léčebného postupu pomocí technologie BCI

Objectivization of treatment procedure using BCI technology

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Key words: *brain-computer interface, distributed systems, cloud-native, NoSQL database, Kubernetes, machine learning, medical treatment objectivization*

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ABSTRAKT

Pacienti, kteří prodělali cévní mozkovou příhodou mohou být postiženi zhoršením pohyblivosti horních a dolních končetin. Snížením těchto následků se zabývají různé rehabilitační techniky. Cílem této práce je návrh architektury informačního systému pro objektivizaci výsledků těchto technik. Systém využívá autorem navržený referenční rámec pro sběr a výměnu dat souvisejících s mozkovou aktivitou jedince. Data jsou získána primárně pomocí zařízení pro snímání mozkové aktivity pacienta a z rehabilitačních přístrojů. Sekundárně se pak jedná o data z primárního a klinického výzkumu a o záznamy uložené v pacientských informačních systémech. Systém poskytuje prostředky pro analýzu těchto dat a hledání skrytých souvislostí mezi nimi. Tato analýza může být využita, jak pro objektivizaci přínosů jednotlivých rehabilitačních technik, tak pro zlepšení vlastností zařízení pro snímání mozkové aktivity. Navržený systémem je koncipován, jako distribuovaný a využívá metodu kontejnerizace aplikací.

ABSTRACT

Patients who have had a stroke may be affected by impaired mobility of the upper and lower limbs. Various rehabilitation techniques are involved in reducing these consequences. This work aims to design an information system architecture for objectifying the results of these techniques. The system uses the author's proposed reference framework for collecting and exchanging data related to an individual's brain activity. Data are obtained primarily using devices for sensing the patient's brain activity and from rehabilitation devices. Secondly, these are data from primary and clinical research and records stored in patient information systems. The system provides the means to analyze this data and find hidden connections between them. This analysis can be used to objectify the benefits of individual rehabilitation techniques and improve the properties of brain activity sensing devices. The designed system is conceived as distributed and uses the method of containerization of applications.

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1   INTRODUCTION

Each year, approximately 13.7 million patients [9] suffer a stroke worldwide, and the trend in the number of newly affected patients is increasing. The expected consequences of strokes include partial or complete paralysis of the patient's upper and lower limbs or complete immobility. In medical practice, standardized physiological tests [17], for example, FMA [1], deal with the objective assessment of the overall state of movement of a patient and his or her limbs. In rehabilitation practice, these testing are usually performed before the treatment process and after its completion. The rehabilitation process aims to reduce the paralysis and limitations caused by a stroke or, ideally, eliminate it. In addition, current scientific knowledge has confirmed the existence of a phenomenon called *neuroplasticity* [4], which supports the partial or complete restoration of the patient's original motor ability during a properly managed treatment process.

This dissertation aims to analyze this phenomenon in patients in rehabilitation practice after a stroke using the brain-computer interface (BCI) [16] device and design a system that will help objectify the treatment process results. The work builds on the published knowledge of BCI use for rehabilitation [15], from research activities and clinical evaluation studies [13]. However, despite the partially positive results of these studies, which support the theoretical foundations, the use of BCI in rehabilitation practice has not yet been expanded [8].

The main obstacles to the use of BCI, in the real-world mentioned before, include [15] the long initialization time (in the order of tens of minutes) required to calibrate BCI at each use, the low spatial resolution to detect the origin of brain activity, and high susceptibility of the device to individual's movements during the sensing of brain activity [11].

One way to remove or reduce these barriers is to improve the various parts of the brain signal activation and management process using machine learning methods. However, insufficient data related to individuals' brain activity do not allow using these methods in practice [6] yet. The author proposes the

Framework for collecting and exchanging data on an individual's brain activity (see Figure 4.1) and an information System to support this Framework in chapter 4.3. The System architecture's design is based on the cloud-native [7] technique. Appropriately implementation of this System in practice can contribute to improving the parameters of BCI equipment. This device and System can then be used to objectify the medical rehabilitation procedure. Chapter 4.3 is therefore partly devoted to choosing the proper methodology for System implementations. Moreover, the design of two specific applications is contained in the same chapter.

2 STATEMENT OF THE PROBLEM

The issues addressed in this dissertation are multidisciplinary and contains knowledge and insights from several disciplines, including neuroscience, imaging methods in medicine, signal processing, machine learning, and information systems theory. Space is devoted, therefore, to each of these disciplines in the state section.

A BCI device [16] captures an individual's brain activity and transforms its image into a format suitable for its processing in subsequent information systems or devices. Promising areas [3] for the use of information, obtained in this way, including the professional training of employees, the operation of equipment and machinery, and the increase of concentration in the profession's performance [12]. Furthermore, a disabled applicant can access professions, and stroke-affected patients could end their rehabilitation process with better output. Possible ways to improve BCI models have described in the article *A Review of Classification Algorithms for EEG-based Brain-Computer Interfaces: A 10-year Update* [11], which deals with the study of new findings and trends in the field of algorithms for acquisition, extraction, and translating the obtained signals by EEG. The paper discusses which algorithms have proved their worth in the BCI area. Adaptive Gaussian, adaptive LDA, semi-supervised CSP + LDA, and adaptive LDA/QDA classifiers proved to improve the general BCI model. It is recommended to use the fastest possible yet stable classifiers,

ideally online with the highest possible SNR ratio, to apply BCI in practice.

The article by O. Faust - *Deep Learning for healthcare applications based on physiological signals* [6]analyzes the knowledge from 53 published works on the use of deep learning (DL) methods for signal processing recorded using EMG, EEG, ECG, and EOG modalities. This analysis's output is that 31 of these works rely on the same data-sets that do not contain enough information to train the deep neural network. The article by J. Kim - *Application of Machine and Deep Learning Algorithms in Intelligent Clinical Decision Support Systems in Healthcare* [10], contains a search of the use of deep learning methods of support systems in decision making in clinical practice with the same conclusion as the previous article [6]. The authors of this research **encourage creating a methodology for collecting and using data obtained and used by BCI devices**.

The field of BCI is relatively young and theoretical promising. As was described in previous chapters, pilot study results have not yet been fully translated into practice in any area of BCI's possible use. One possible use of the BCI is in rehabilitation practice, which has focused on MI feedback supplement current treatments now.

Moreover, several barriers like a long-time process of BCI device initialization, necessary in its every use, lasting tens of minutes, and the total time required to capture the individual's wishes and translation for further machine use lasting about 30 seconds were found. On the other hand, several directions can lead to the removal of current barriers. Advanced machine learning tools could improve the processing of recorded brain signal activity and its extraction. Using spatial mapping to determine the origin of brain activity instead of source-local could better transfer theoretical knowledge of neuroscience to the BCI environment [12].

3   RESEARCH AIMS

The main goal of the dissertation is to objectify the results of various treatment procedures in rehabilitation practice using BCI (Brain-Computer Interface) and the proposed software architecture. The author wants to achieve this goal by fulfilling the following objectives:

1. Design a system architecture following the principles of advanced SW engineering, which will support the existing objectification methods used in clinical rehabilitation practice, to compare the effectiveness of individual treatments using BCI devices,

2. compilation of methodology for long-term use of the proposed system in the clinical practice of several health care facilities and its improvement.

4   SYSTEM ARCHITECTURE AND METHODOLOGY

4.1   Framework BCI

Based on the knowledge gained in studying BCI's current use in practice and theoretical possibilities for its improvement, a new Framework for BCI use in healthcare was proposed. Its structure is depicted in Figure 4.1.

The object of interest of the Framework is the collecting and subsequent storage and sharing of records obtained using BCI devices, sensors, or cooperating information systems. Subsequently, the use of the information in these records improves the BCI model's properties and could help scientific research in the areas using these records. To achieve this goal, the Framework provides tools for the application of machine learning elements. Simultaneously, the information obtained in this way can be used in a work task or for their evaluation. An example of this can be determining the direction of movement of a controlled
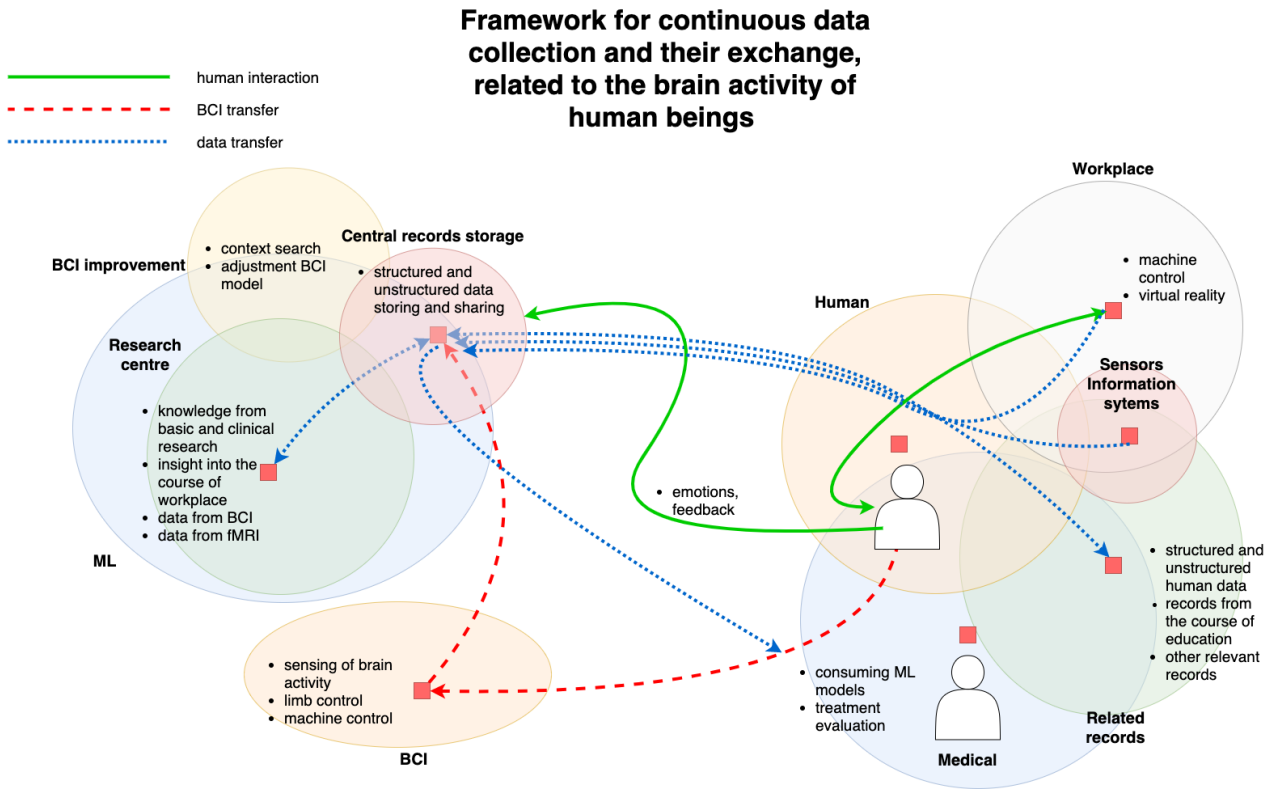
Fig. 4.1 Framework for collecting and exchanging data on an individual's brain activity. [Author]

machine by analyzing an individual's brain activity and translating this intention into a form suitable for the controlled device or evaluating the degree of concentration in performing a work task.

The Framework's right side represents the actors, machines and equipment, sensors, and information systems that are the primary originators of this information. At the same time, this right side can be the recipient of instructions that the BCI device has identified for machines and devices or information systems when sensing brain activity.

The left side of the frame, on the other hand, represents an environment for improving the BCI model. This environment includes tools for applying machine learning elements to support this goal. It uses the records created in the right part of the Framework and the records and knowledge gained by basic and clinical research in the field.

Because the frame contains its left and right side, they are mutually enriched.

The data obtained during the performance of work tasks can improve the BCI model and lead to a broader application of BCI in the work environment in practice. This process can be continuous and long-term.

4.2 Application's design

The objectification of the treatment procedure will be performed by repeated (before, during, and after treatment) analysis of the power of brain activity oscillations. Mobile EEG [5]in predetermined areas of interest of the wave spectrum of these oscillations (motor system waves in the band 7- 13 Hz and central beta waves in the 13-30 Hz band, see [14] and [2]) related to the conscious performance of tasks will be used.

The patient will perform an imagination of the movement of a specific physical activity or activities of the affected upper limb. Power analysis will use the amplitude changes of the subject brain waves (ERD / ERS) between the preparation and performance parts of the imagined activity. The phenomenon described above is used by two proposed applications to support the objectification of rehabilitation methods.

4.2.1 Application 1 for objectivization

The application App1 will use the analysis of power spectrum for a given wavelength of electrical brain activity sensed by BCI (EEG) to evaluate whether the brain centers responsible for the preparation of movement after evoking activity have been activated. The application will work with real-time evaluation thus can be used directly in rehabilitation. The application will use a prepared neural network, which will perform the classification. It will classify which centers were activated during the rehabilitation task. The neural network will be trained with knowledge - supervised.

The Figure 4.2 depicts a conceptual diagram of this application. The medical starts the rehabilitation task and enters this information with the task's pa-
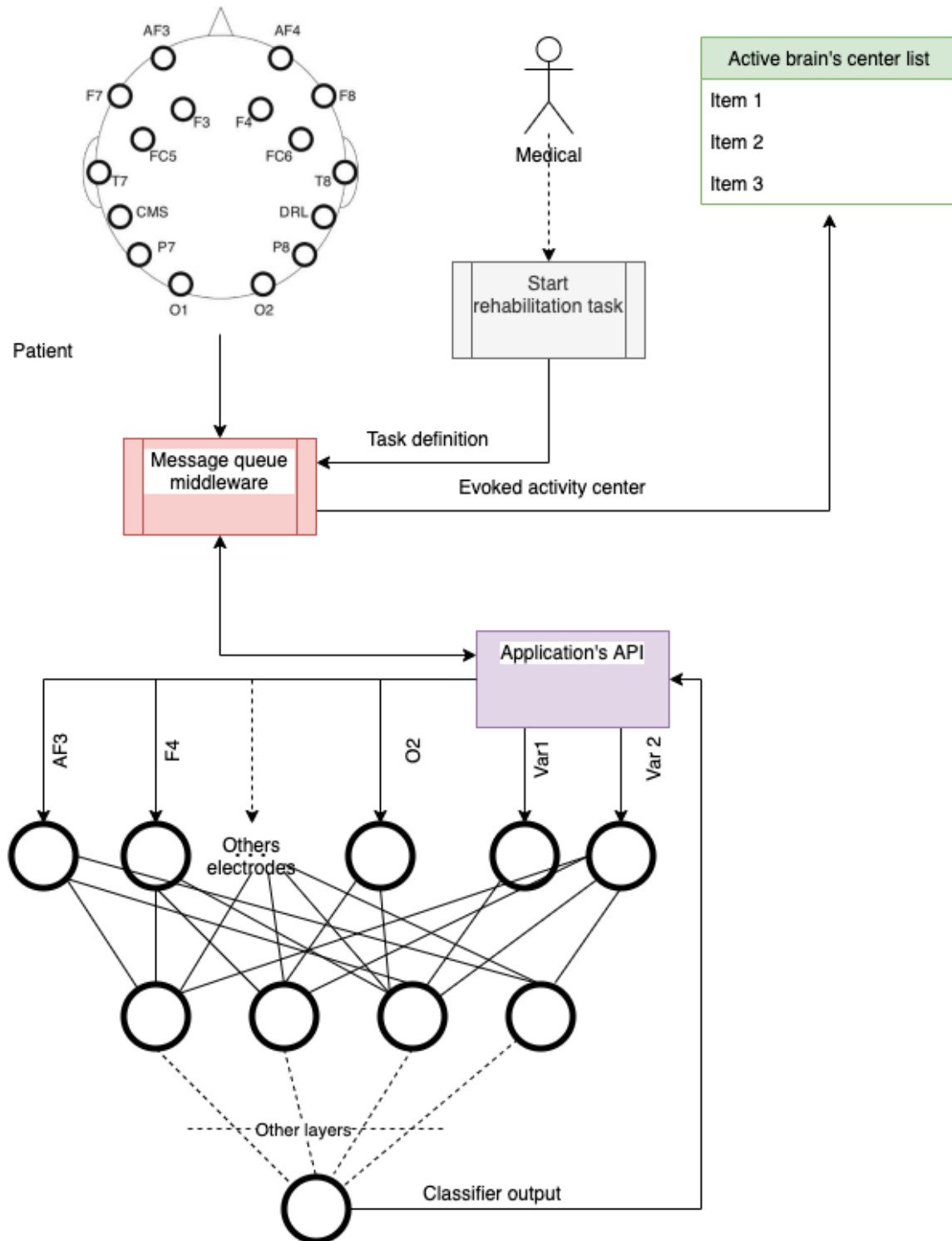
Fig. 4.2 Conceptual schema of real-time brain-center evoked activity feedback. [Author]

rameters from the predefined template to the application. The patient begins to perform the task, and the BCI device senses his brain activity. The defined parameters and the record of evoked brain activity are captures by message

queue middle-ware and sent to the neural network API. Neural network takes this information as its input. In the figure, they are labeled as Var 1 and Var 2 and AF3, F4, 02, respectively. The trained neural network then estimates which brain centers were involved in the desired task and passes this information to the physician's screen.

4.2.2 Application 2 for objectivization

The application will objectify the result of the rehabilitation with the context of the results of rehabilitation in other patients. Medical records, patient history, method and type of rehabilitation, rehabilitation tools and techniques, and electronic output from rehabilitation devices will be compared. They will also include records of induced brain activity captured by the BCI device.

The application will use a prepared deep neural network, which will evaluate a vast amount of input data to objectify rehabilitation using the clustering method. Therefore, the output will evaluate the treatment outcome in terms of comparison with other patients and their treatment. The neural network will be trained without knowledge - unsupervised.

4.3 Informational system and data flow

The design of the Information System must respect the requirements for the collection of relevant records, their storage, and analysis. Data protection must be observed. In this work, processes for such workflow support were identified.

An individual or an external stimulus induces the brain activity of the patient. The BCI captures the image of this brain activity. Subsequently, two processes of processing the captured activity take place in parallel. In other parts of the BCI, signal extraction and its translation of the estimated intent of brain activity in the first process with subsequent storage of the output in the local and central data storage in the first process occur. In the second, the raw data obtained from the EEG part of the BCI are stored in a local environment where
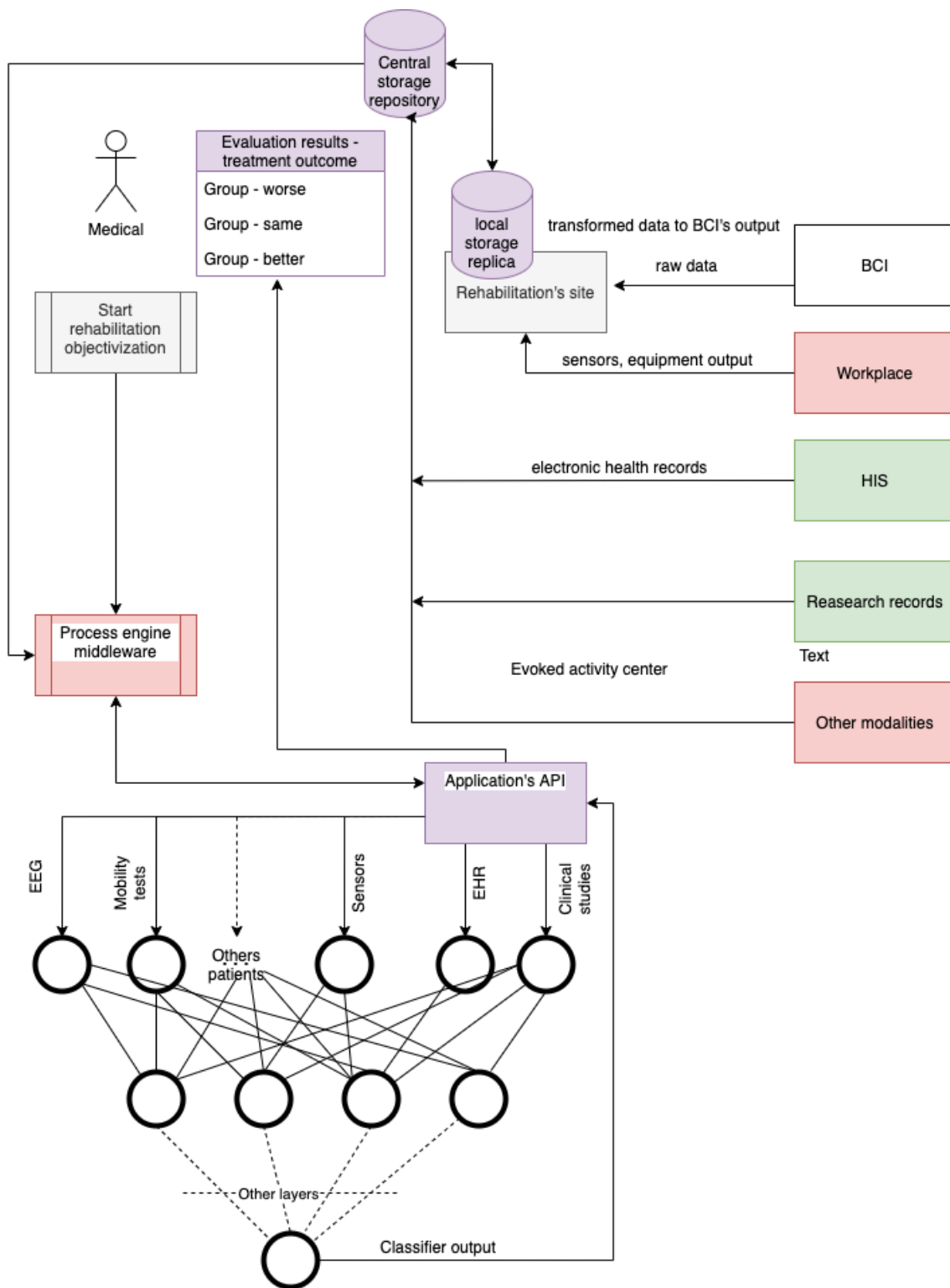
Fig. 4.3 Conceptual schema of individual's treatment objectification against other patients using large data volume and input. [Author]

rehabilitation is performed and are transferred asynchronously to a central data repository for further use. Thus the failure of the data connection is ensured. The raw data format of EEG could be helpful, for example, to analyze this

data to improve BCI's processing signals methods of brain activity images.

These records are supplemented with information related to their origin when stored in the central data storage in both cases. They may include but are not limited to a record of the patient's medical history, a record of the purpose of the rehabilitation procedure, information on the rehabilitation techniques and tools used for rehabilitation, and a sensory record of the instruments or devices used. The process can be seen in Figure 4.4. The data obtained on
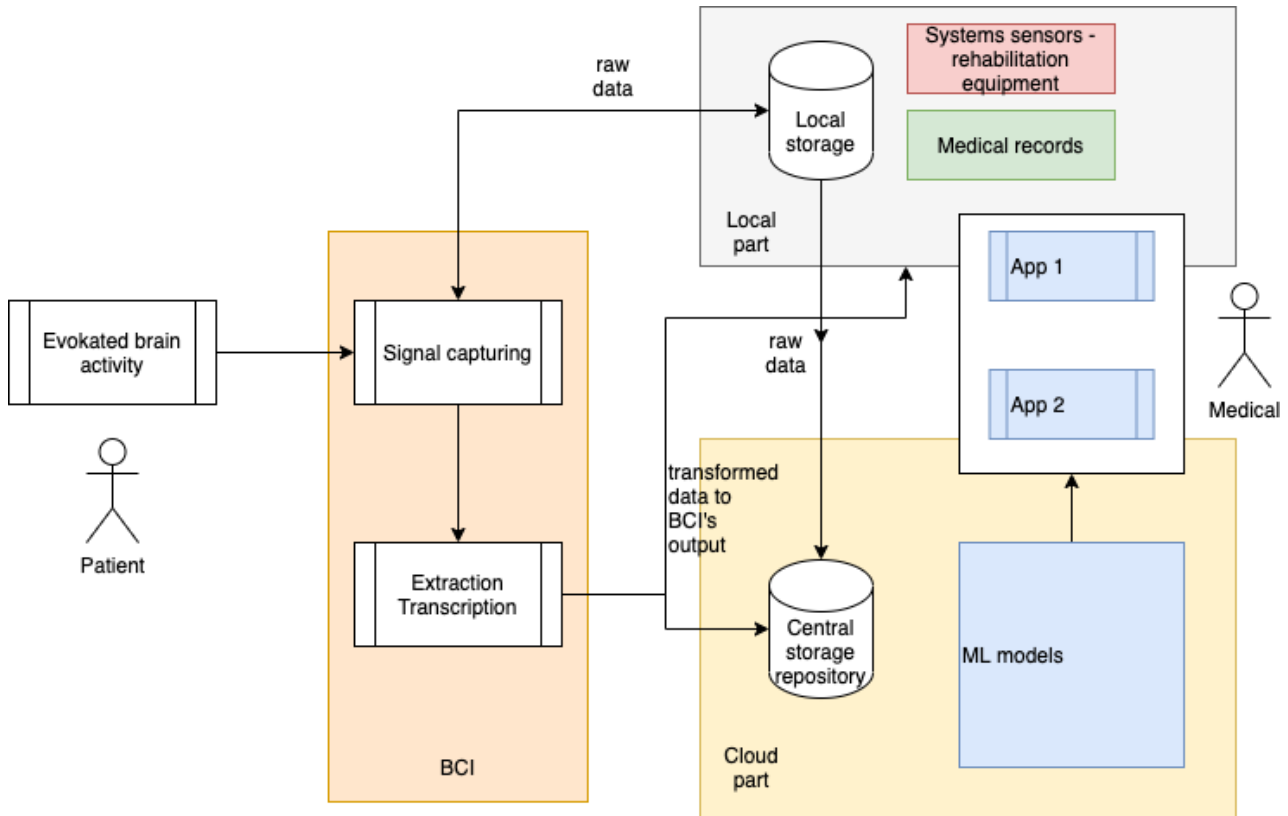
Fig. 4.4 Data flow of sensed brain activity. [Author]

the individual's brain activity and associated records can be used by applications hosted in a local or cloud environment, depending on the complexity of the applications in the required machine power, data throughput between cloud and local environment, and time required to obtain the demanded result. The design of two specific applications to support the objectification of rehabilitation methods is described in detail below in this chapter.

Figure 4.5 depicted a scheme of support for scientific activities. Raw data from the BCI or their transposed image in the form of the output of the expected brain activity and data related to the rehabilitation site (Workplace)
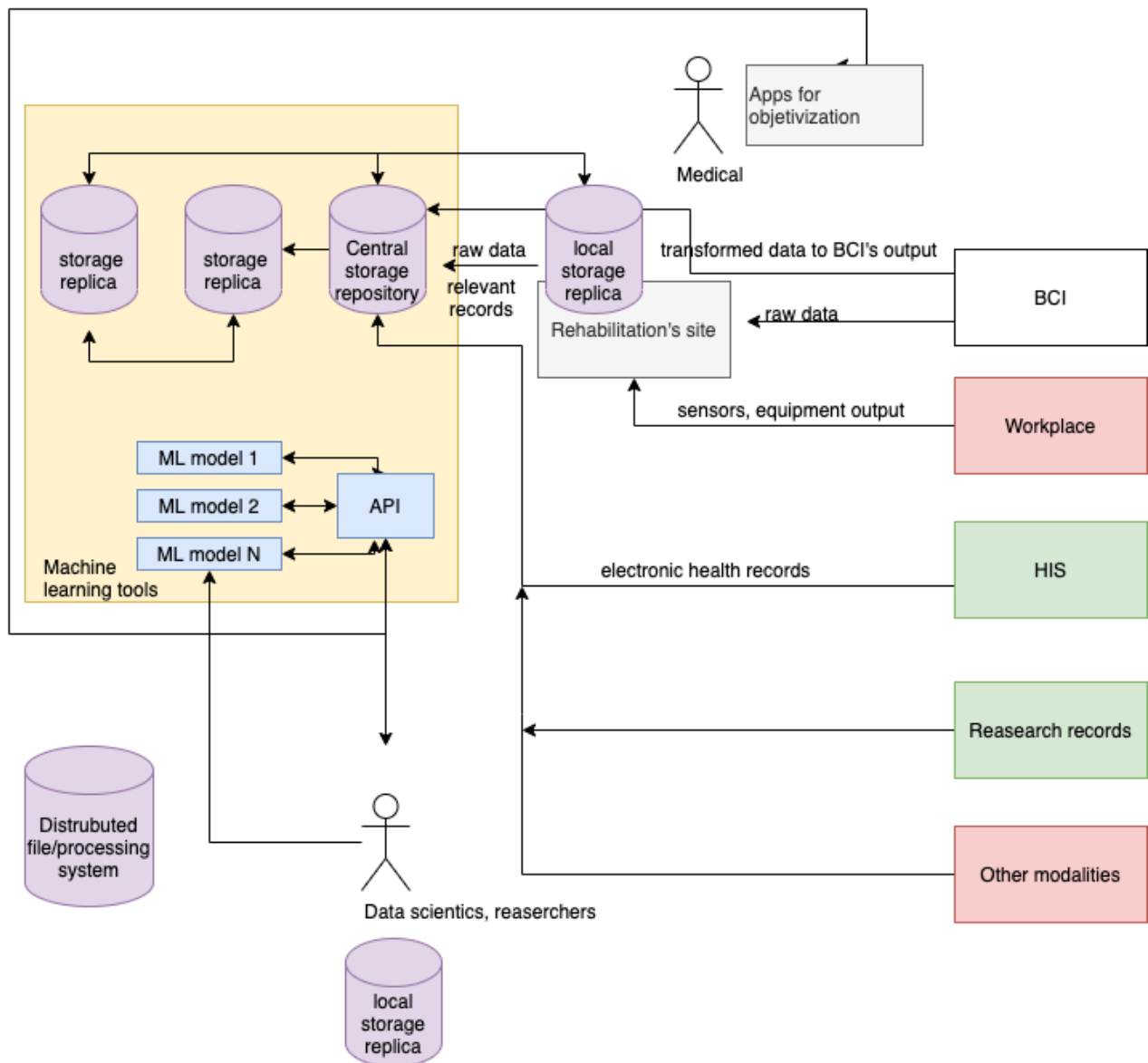
Fig. 4.5 Data flow of BCI and other records storing in repository and their using by researchers and other actors. [Author]

are stored in the local and central storage repository. The local repository is used to store raw BCI and other equipment obtained at the rehabilitation site to minimize the possible loss of this data during transmission and eliminate the disadvantages of remote network connection. The output of the BCI processing process is then stored directly in the central repository.

The designed Information system uses the Cloud-Native principle. The container technology was selected to run the application and RESTful API for communication with the surrounding environment. A persistent volume is used for data storage, which is also used by SQL and NoSQL databases. The

distributed system's architecture was chosen concerning the expected overall complexity of the information system and its demands. Kubernetes was selected to manage such a system and orchestrating the allocated resources based on the system's requirements.

This choice determines the basic architecture of the system. The Kubernetes cluster has two separate parts. The first part is the control one and contains the Control plane. The second part is responsible for performing work operations and consists of at least one computer - a node on which the so-called PODs are running. They then host containerized applications. The Control Plan's task is to allocate the necessary physical resources from one or more work nodes to these applications and provide network services based on predetermined requirements. These requirements may depend on the containerized applications' required output power and may be changed dynamically depending on their fulfillment. The Control plane itself is usually operated in multiple replicas due to the demands on its availability.

Cloud patterns were deeply discussed to tightening operational and functional requirements demanded on the System together. Cloud patterns were deeply discussed to tightening operational and functional requirements demanded on the System together. These patterns include Application Workloads, Cloud Service Models, Cloud deployment Models, Cloud Environments, Cloud Application Components, Multi-tenancy, Native Cloud Applications, Processing Offerings, Storage Offerings, Communication Offerings, and DevOps.

5   MAIN RESULTS

The primary goal of these Thesis was to objectify treatment methods using BCI devices. The knowledge gained during the study of the art study revealed the necessity to improve BCI-type equipment's properties. Primary machine learning methods can be used to strengthen them. For their use, however, it is necessary to increase the amount of relevant data. The Framework for BCI support was designed to support this idea. Subsequently, the Framework's

algorithmization parameters were defined, and then the Information System was designed to meet them. The following findings were found:

1. **Specific wavelengths of action potential** suitable for the analysis of the activation of the brain centers responsible for the preparation and implementation of the movement were identified. This finding is **used by the objectification support applications** proposed in these Thesis.

2. Given the number of independent workplaces using the Information System and how they work with data, it seems to be the right choice to design this system as distributed.

3. Due to the nature of the unevenly distributed load, it will be appropriate to choose a cloud environment that supports this requirement. Local resources should be used as a raw recording environment of brain activity processing with subsequent data transfer to the Central Storage Repository for some operations. For this purpose, the file system was chosen as distributed, and rules for its operation were set

4. **A middle-ware data platform was chosen** to support data flow between Workplace, BCI, HIS, IoT things, and the Central Storage Repository. Rules for data consistency and integrity were defined. Also, parameters for data availability depending on its nature and processing type were chosen.

5. A particular environment was set to support ML techniques and their computationally intensive operations. **Principles for the exchange of large-volume data and the use of data subsets for the creation and evaluation of ML models have been defined**. Thanks to this, it will be possible to use hardware resources in the Information System that support these operations.

6. The CRISP-DP Framework was chosen to design applications using ML tools, and its steps were explained.

7. A particular part was devoted to data protection. GDPR requirements positive for this system were defined, and these requirements were mitigated. Anonymization was suggested to protect sensitive records. They

can be used for scientific purposes or by other health organizations furthermore. Also, data protection during their transfer from their place of origin to the Information System was applied.

8. To ensure the integrity of patient-oriented data in a distributed environment and when using a **distributed file system**, it is necessary to choose a technique so that such integrity cannot be called into question in the future. The application of blockchain technology seems to be suitable. Within the work, **specific blockchain technology was chosen**.

9. For data transfer from rehabilitation devices or sensors and imaging modalities, it was proposed to use MQTT-oriented middle-ware architecture, and data **consistency and integrity requirements were defined**.

10. **Two specific applications using BCI for objectification have been proposed**. One is used for immediate feedback on activating the desired brain areas when the patient performs the assigned task. The second is to compare the success of treatment of a particular patient with other patients with similar input parameters affecting treatment.

11. Because up to 80% of patient records do not have a structured data format, it is **appropriate to use the NLP method to analyze** them. Suitable types of records for this operation were identified within the work, and appropriate techniques were chosen.

12. Several hundred data formats are used to store medical records. Data of this nature will be stored in the Central Repository in the EU-specific format for **EHR interoperability**. As part of the middle-ware architecture for data transmission and processing, data transformation will be performed from and to this format for communication with existing Hospital Information Systems.

13. The **Kubernetes environment was chosen for hosting the Information System**, its administration, and orchestration of resources. The

design of an appropriate deployment of this environment and its operational requirements were defined. With this choice, it was possible to realistically consider meeting the technical and operational requirements related to the Information System.

14. In connection with the choice of environment, the **Cloud-Native technique was also chosen to develop and operate individual applications**. As part of the solution, it is proposed to use single-purpose lightweight applications and micro-services. They will communicate with each other and pass on their outputs for further processing. It will ensure the readability of the code and facilitate its re-usability.

15. **The methodology for the operation of the Information System was defined. This methodology respects Kubernetes, Cloud-Native, Framework, and application requirements. It also supports compliance with the GDPR and, in general, the protection of sensitive data stored in the system**.

16. An environment was defined for activities related to the improvement of the BCI model using ML technologies. Procedures for its use and data flows have been defined.

17. The transport sector was identified as a promising area that can benefit from this Thesis in the future.

The above findings are interrelated and form an overall unique view of the Thesis focus.

6 SCIENTIFIC CONTRIBUTION

The benefit of the work for science and practice is the designed and verified architecture of the distributed system for further use, following the set methodology, enabling long-term, related activities of scientists from various fields of their activity (computer science, rehabilitation, neuroscience). Furthermore,

the use of this system for the objectification of rehabilitation methods in clinical practice. **The proposed Framework, Information system, and applications are unique and use the opportunities of BCI technologies, modern distributed systems, and Cloud-Native methods**.

The benefit will also be a closed information circuit enabling mutual use of knowledge from both parties involved, which are listed above. It will be possible for the scientific party to obtain anonymized patient data and related measured data in practice. The lack of this data is one of the leading causes of the current stagnation in the use of modern data processing methods using elements of machine learning in the field of biomedicine.

On the other hand, clinical practice will provide a tool to support current methods for evaluating treatment success. This tool will use scientific knowledge from the field of neuroscience to confirm the occurrence of brain plasticity in the presumed area of interest and, at the same time, capture several inputs and ongoing data about the patient himself. Two practical applications for the objectification of rehabilitation methods using BCI were proposed. Thanks to this, medical staff can receive additional objective information about the patient's condition during rehabilitation and completion. He can then use this information to his advantage or the benefit of other patients.

The use of this tool could also be helpful for the treatment of other diseases, such as Parkinson's or Alzheimer's. In the long run, this approach can help create another advanced tool for rehabilitation practice (CDSS), which would assist medical staff in determining the rehabilitation procedure. To set up and train such ancillary software of clinical practice, the data already obtained from the system designed according to this dissertation would be used.

The whole Framework is transferable to other branches of human knowledge. It is ideal for collecting data from different sources and working with them for a long time using ML techniques. Areas identified in this way include, for example, transport and agriculture.

7 CONCLUSION

The primary goal of Thesis was to objectify the outcome of treatment methods for stroke patients using the BCI device. Two main aims have led to this goal. The first was the design of an Information system supporting the proposed Framework of objectification. The second was the proposal of a methodology for the operation of such a system in practice. Within the study of literary sources, the Thesis revealed the possibility to use for this task the analysis of evoked changes in the amplitudes of the electric potential with precise frequencies (ERD/S). The time-domain of preparation and execution of the presented limb movement is examined. The BCI device can be used to record such brain activity.

However, weaknesses in this device have also been identified, which do not allow their use in current practice. Therefore, ways have been proposed to suppress or eliminate these weak points. The use of ML techniques to enhance signal processing seems promising. Two specific applications have been proposed that would use BCI in clinical practice to complement existing objectification methods. According to their design, both of these applications also use ML techniques.

A Framework for the objectification of treatment methods using BCI devices has been proposed. This Framework widely supports the collection and processing of patient treatment-related data. It allows reusing this data to improve the performance of the BCI device. At the same time, it allows the use of this device in applications for the objectification of treatment methods in clinical practice. These two parts complement each other in the long run. The knowledge-able auditorium has positively received this Framework. It was also suggested how the BCI device could be applied in the transport sector using this Framework.

The proposed Framework for Objectification, its parts, actors, data, and information flows was described in detail. Furthermore, the requirements for the Information System that supported such a Framework were defined. These requirements were used when Information System was designed. Subsequently,

the rules and recommendations for its operation were defined. It was found that it is very appropriate for a given Information System to use the architecture of a distributed environment and containerized applications and microservices.

Thanks to this, it was possible to meet all the Framework requirements imposed on the Information System. Part of the work was devoted to the methodology of operation of this system, where possible variants of the cloud environment architecture were discussed in detail. In this part, design patterns were used. The work identified the way to use BCI for the objectification of treatment methods for patients with stroke. The proposed Framework, Information System, and Applications use the power of modern distributed systems. Other researchers and multidisciplinary teams can use this pathway to introduce BCI into clinical practice. As was demonstrated in the transport sector, the findings and proposed solutions can be applied to other parts of the human interest.

8 CURRICULUM VITAE

Name and surname: Vít Štěpánek

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Field of study: Automatic Control and Informatics

Degree: Ph.D. study, currently studying (2021)

Brno University of Technology, Faculty of Electrical Engineering and Communication, Department of Control and Instrumentation, Department of Biomedical Engineering

Field of study: Electrical engineering and informatics

Specialization: Cybernetics of automation and measurement, Biomedical Engineering

Degree: academic title Engineer (2006)

Professional Education:

College of Logistics in Přerov, Institute of MBA and Career Education

Field of study: Logistic

Degree: professional title Doctor of Business Administration (2021)

Jobs:

NWT a.s.

From 1. 9. 2010   to   current time

Job description: Director of the ICT Division

- Responsibility for the operation of the division, economics, personnel matters
- Responsibility for the operation and development of all internal information systems and ICT infrastructure of the NWT a.s. - more than 30 companies
- Design of ICT development solutions for internal and external customers
- Responsibility for the operation of ICT infrastructure and systems at more than 100 companies (personal stations, servers, networks - outsourcing at the companies)
- Management of the development team, operations team, sales, and service team
- Responsibility for compliance with information security according to the international standard ISO 27001
- Member of the company's top management
- **Leader of the project Intelligent robotic protection of the health of the hydroponic greenhouse ecosystem of the primary recipient of the TAČR Trend fund.**

Business and investment support agency CzechInvest

From 1. 7. 2007   to   31 .8 .2010

Job description: Director of the Information Technology Department

- Responsibility for the operation, development of all information and communication systems of the agency. Support for internal and external users - more than 10,000 active users
- Responsibility for the operation of a complete ICT infrastructure in more than ten countries and about 30 locations
- Responsibility for the implementation of the ISO 27001 standard for the entire scope of the agency (**the first certified organization of its kind in the world**)
- Responsibility for compliance with information security according to the international standard ISO 27001
- Member of the organization's management.

Ministry of Health of the Czech Republic

From 30. 1. 2006 **to** 30. 6 .2007

Job description: Ministerial Assistant Principal

- Creation of standards and methodologies for the design and development of information systems of the Ministry of Health
- ISPROFIN program investment plan in the field of information and communication technologies for all organizations within the competence of the Ministry of Health
- Responsibility for internal information systems, ICT development strategies of the ministry and subordinate entities.

Part-time jobs:

Health Information Systems Coordination Center

Duration - two years

Job description: Consultant

- Proposals in the field of development of health registers
- Recommendations in the field of electronic healthcare

Ministry of Health of the Czech Republic, Department of Informatics

Duration - two years

Job: A contract worker

- Proposal of a national concept of ICT development in healthcare - eHealth project
- Member of the eHealth Council, Head of the Telemedicine Section

Ministry of Finance of the Czech Republic, Accounting and Audit Department

From 2009 to 2014

Job description: Technical consultant

- Consultant in the project "State Treasury" for the client site
- Technical and process assessment of solution design, methodology, documents
- Member of the leading working group for state accounting and data consolidation
- Support team member

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LIST OF FIGURES

LIST OF ABBREVIATIONS

API	Application Programming Interface
APP	Application
BCI	Brain-Computer Interface
BMI	Brain-Machine Interface
CDSS	Clinical Decision Support System
CRISP-DP	CRoss-Industry Standard Process for Data Mining
CSP	Common Spatial Pattern
DL	Deep Learning
ECoG	Electrocorticography
EMG	Electromyography
EOG	Electrooculography
ERD/S	Event-Related Desynchronization/Synchronization
FMA	Fugl-Mayer Assessment
GDPR	General Data Protection Regulation
JSON	JavaScript Object Notation
LDA	Linear Discriminant Analysis
ML	Machine Learning
MI	Motion Imaginary
MQTT	Message Queuing Telemetry Transport
NLP	Natural Language Processing
NoSQL	No Structured Query Language
PS	Paired Stimulation
QDA	Quadratic Discriminant Analysis
REST	Representational State Transfer
SQL	Structured Query Language

Vít Štěpánek

Objektivizace léčebného postupu pomocí technologie BCI

Objectivization of treatment procedure using BCI technology

Dissertation thesis statement