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Measuring system for EEG analysis of brain impulses and visual interpretation of dreams using AI

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Abstract—This research focuses on the analysis of brain impulses in a large number of subjects during the presentation of various images, using EEG technology. By monitoring brain activity, researchers identify patterns associated with specific types of images, allowing for a deeper understanding of reactions to visual stimuli. The data are stored in the database, and the server uses artificial intelligence to process the information from the smart EEG device. Data security is essential, with encrypted communications between devices and servers. Artificial intelligence generates stories and visual representations of dreams based on textual descriptions and images, providing users with unique visual experiences.

Key words—EEG analysis, dream recording, artificial intelligence, cryptology, security, smart watch, smart cap, brain impulses.

I. Introduction

Research and analysis of sleep quality have become crucial factors in maintaining health and well-being. A deeper understanding of neurological processes during sleep can provide valuable insights into mental health and cognitive functions. In this context, the integration of artificial intelligence (AI) and electroencephalography (EEG) represents a promising methodology for the analysis and interpretation of EEG signals during sleep. According to the authors' knowledge, such a system does not yet exist. Recent studies have shown that deep learning and advanced machine learning techniques can effectively classify sleep stages using EEG signals. The combination of deep learning and EEG analysis enables automatic recognition of different sleep stages with high precision, including the rapid eye movement (REM) stage, which is associated with dreaming. One of the main challenges in analyzing EEG signals during sleep is the complexity and individual variability of these signals. However, advanced deep learning techniques allow models to learn complex patterns in EEG signals and effectively use them for sleep stage classification. The contribution of this work is the integration of AI and EEG for sleep analysis with the aim of improving understanding of neurological processes during sleep, recognizing specific patterns and images depending on the obtained EEG signal, and interpreting a sequence of images in the form of a video generated by AI. We focus on the application of deep learning and advanced machine learning techniques for automatic recognition of sleep stages and analysis of dream content during the REM sleep stage. Through a detailed analysis of relevant studies and methodologies, we will explore the potential application of these techniques in clinical practice, as well as potential benefits for dream research, mental health and understanding of cognitive processes during sleep. This work aims to contribute to the development of advanced technologies for sleep analysis, providing new insights into neurological processes and contributing to the improvement of health and well-being.

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II. Goal of the Research

The work is innovative and is based on a hypothesis that describes a number of already existing technologies connected into one whole. The contribution to science as well as the goal of this research is to enable people to have insight into their dreams, to be able to monitor the quality of their sleep, and perhaps even to help them solve problems such as nightmares or insomnia. The first step of development would be research of brain impulses in a large number of subjects while they are shown a large number of pictures of different objects, people, animals etc. By monitoring EEG signals, the researchers will analyze subjects' brains to identify common patterns of activity associated with the same types of images. This will help us to better understand how the brain reacts to visual stimuli and to find possible common patterns or reactions that are characteristic of certain types of images. We place the processed EEG signals in the database, each signal in the database will be linked to the image that was shown to the respondents and each signal will have a corresponding textual description of the image [1]. An especially important part of this system is server that will use the information of the entire research

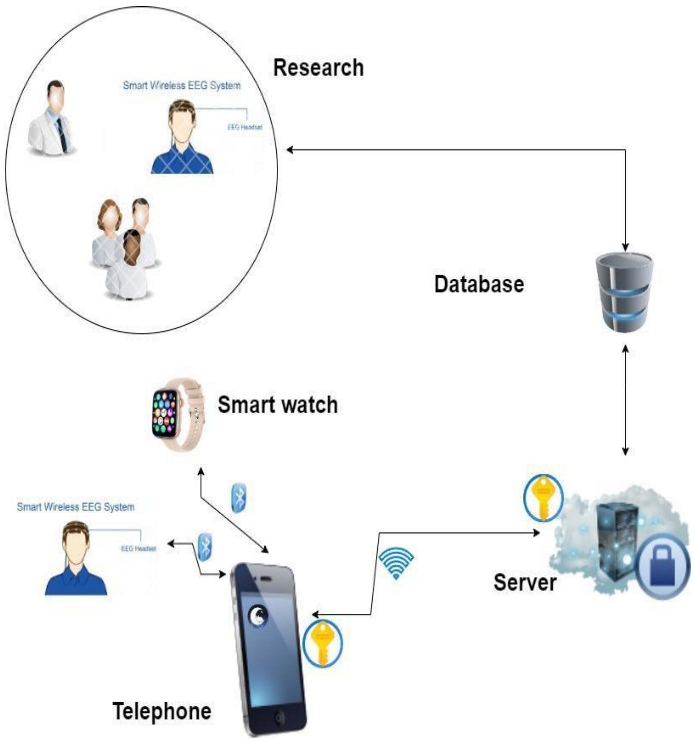

Fig. 1. Schematic representation of the dream recording process

paper that is in the database. That data will be stored by artificial intelligence located on the server itself. Based on the data that the server receives from the phone, the artificial intelligence will process the received data (smart EEG recordings) and recognize certain patterns that are stored in the database. The images as well as the textual parts of the images that are related to those specific signals that arrived from the phone will be sent to the AI, which will generate a story based on those descriptions and then generate a series of frames from which we will receive a video, that is, a visual representation of our dream. It is especially important to take care of data protection in this case. The communication between the phone, the server and the smart cap is encrypted with the highest levels of protection. AI will not receive personal information about users, only plain text and an image related to a specific EEG signal. The "smart cap" is the way in which the signal is recorded on an individual, and the cap would be connected to the phone. While the phone communicates with the smart watch as we can see in Fig.1, the task of the smart watch is to detect movements, heart rate, blood oxygen level, breathing as well as REM phases and deep sleep, on the basis of which it can give information to the phone that will wake up the EEG device and start recording based on the detection of REM phase. Why only in the REM phase? Because we dream only during the REM phase and other data during the night are not important to us. We save the EEG battery as well as the time of data processing itself [2].

III. Research

In the following paragraphs, we plan to thoroughly elaborate on each individual segment to provide a more detailed insight into our methodology and research. The research itself begins by conducting a survey on a larger group of people to whom we will show pictures of different objects, animals, plants, etc. As part of the research, we plan to use three types of visual stimuli to achieve a comprehensive understanding of dream content [3]. These stimuli include abstract images, emotionally charged images, and representations of everyday life. Examples are pictures can be seen in Fig. 2. Abstract images serve as stimuli for exploring the process of association and interpretation at the neural level. EEG measurements allow the recording of electrical potentials during exposure to abstract images, thus providing insight into rapid brain responses to abstract stimuli. Emotionally charged images are used to identify specific brain regions and electrical activity associated with emotional experiences. The EEG smart cap allows monitoring of electrical changes on the surface of the scalp, providing information on the temporal dynamics of brain activity during the display of these images. While connecting with real situations can result in emotional and cognitive responses. Identification and interpretation of abstract images

Fig. 2. Presentation of an emotional and abstract image [10]

Fig. 3. Smart cap [11]

can be challenging due to the subjectivity of these processes, and the results can be subject to individual interpretations. Emotional responses, which vary among respondents, further complicate the research. Connecting with real situations can result in both emotional and cognitive responses, taking into account that the same everyday situations can cause different emotional reactions in individuals. It is important to note that some images can also cause negative reactions, which further contributes to the variability in the experimental results. Predefining the temporal parameters for the presentation of visual stimuli, as well as carefully planning the sequence of displaying images are key factors in neurocognitive research. In addition, considerable attention is paid to the selection of target groups of respondents, including demographic characteristics such as age, gender, and previous dream experiences. These variables have an important impact on the interpretation of the results and the generalization of the findings, allowing a more precise understanding of the impact of visual stimuli on brain processes in specific populations.

An innovative EEG smart cap will be placed on the examinee's head, which enables recording of the brain's electrical activity during the phase of imagining the objects shown in the images. The smart cap will be implemented from a comfortable and pleasant material that will provide the user with comfort and quality sleep, which we can see in Fig. 3. In addition to the comfortable material from which the cap will be made, inside the cap will be EEG sensors, gyro-sensors, Bluetooth module, battery and memory. EEG sensors will monitor the electrical activity of the brain and will be able to detect various stages of sleep. Gyro-sensors are sensors that measure movements and orientation of the cap during the night, which can contribute to the interpretation of dreams. The Bluetooth module is used to connect to a smartphone that communicates with a smart watch in the same way. The cap should have a built-in battery that allows enough recording time during the night and memory to store dream data while the cap is not connected to the phone. This integrated technology aims to accurately record neurological data during sleep and enables remote communication with smart devices to analyze and interpret the information obtained [4]. In order to have a highly calibrated EEG system during the research, we will use electrodes with high resolution, real-time monitoring, individual calibration, filtering and signal processing. Precise calibration starts with high resolution. Increasing the number of electrodes and their precise placement on the scalp enables better recording and differentiation of brain activity. Each person has unique brain characteristics, so system calibration is important for each individual. This may involve adjusting the parameters in the EEG signal analysis algorithms to obtain the best results for each individual. Real-time monitoring enables system adaptability during the experiment itself. If changes in EEG signals or the need for adjustments are detected, the system can react immediately. Accurate calibration also includes appropriate filtering of the EEG signal to eliminate interference and obtain a cleaner signal that can be used to generate images or videos.

IV. DATA STORAGE AND PROCESSING USED BY AI

After the collected data using EEG recording, data analysis is performed. Fig. 4 shows the EEG signal in different frequency bands. Specialized EEG data analysis software is used to analyze the data to identify patterns of brain activity associated with imagined movements. Each object will be assigned a corresponding signal that was created during the data analysis and a short textual description of the object that was shown to the respondent. All of this will be stored in the database. As already mentioned, the server uses all the data from the database and based on the information received from the phone creates a video and a short story for the user. The system works within the framework of artificial intelligence, where the data obtained from the database and the information sent from the smartphone are subjected to processing through an artificial intelligence model known as ChatGPT. This model specializes in natural language processing and user input analysis. The application of the artificial intelligence model within this research is not limited to the exclusive use of ChatGPT, but its selection is determined with regard to the recognized reliability and stability. In future development, as a contribution to this research, the possibility of creating a special artificial intelligence module, instead of using ChatGPT, is being considered, with the intention of achieving an additional level of reliability and stability within the analysis and processing of data. In parallel, the creation of videos is realized using "Image Processing" AI technology, which includes the application of algorithms for the analysis and manipulation of digital images in order to generate video content. The EEG data will be segmented into time epochs corresponding to the time periods when certain stimuli were presented. This allows analysis of how the brain reacts to each individual stimulus. Extracting relevant information based on brief descriptions of objects in the database, AI can identify which parts of the EEG signal relate to specific objects or types of stimuli. This step may involve methods such as frequency filtering or applying different shape recognition algorithms to identify characteristic EEG responses to certain visual stimuli. Based on the identified information, AI can generate images or videos that reflect visual representations of what the subjects saw. To make the video as accurate as possible, machine learning techniques and precisely calibrated EEG systems are used [5]. The machine learning technique that will be used in this research paper is Generative Adversarial Networks (GANs) [6]. The basic idea of GANs consists of two main elements: a generator and a discriminator. These two parts of the network compete against each other, resulting in an iterative improvement in the quality of the generated data over time. The generator has the task of creating a new data instance that should look as similar as

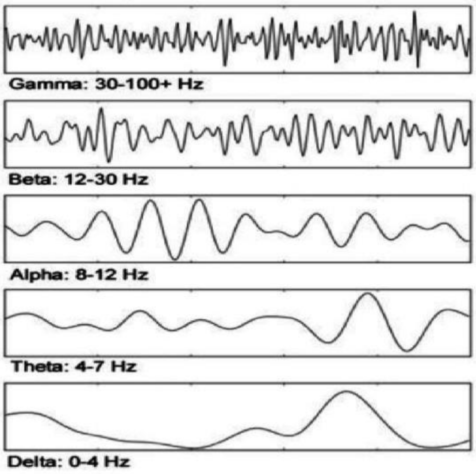

Fig. 4. EEG signal recording [12]

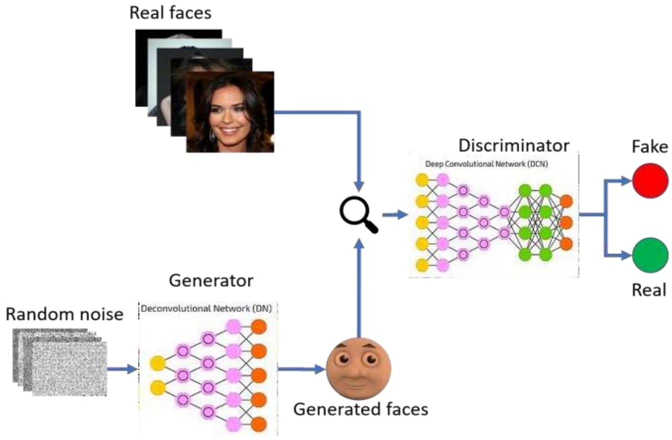

Fig. 5. Generative Adversarial Networks (GANs) [13]

possible to the real data from the training set. At the beginning of training, the generator usually produces poor results. The discriminator has the role of distinguishing between the real data and that generated by the generator. A discriminator is basically a classifier that tries to recognize whether a given piece of data is real or generated. The process of training GANs consists of several iterations between the generator and the discriminator. In the first segment of the operation, the generator generates new data while the discriminator tries to distinguish the generated data from the real data. In the second phase, the generator adjusts its generation process based on the errors identified by the discriminator and tries to produce data that is as realistic as possible. This iterative cycle between generator and discriminator contributes to achieve better quality results in generative models. This process is repeated, leading to improvements in both parts of the network over time. When the GAN finishes training, the generator is capable of producing data that is very similar to that of the training set [7]. In Fig. 5, we see an illustrative representation of the functioning of GAN.

V. COMMUNICATION ENCRYPTION AND APPLICATION DEVELOPMENT

It is crucial to pay attention to data security aspects. Within this technological implementation, it is insisted on the application of the highest standards of data protection during the communication between the smartphone and the central server, as well as between the smartphone and the smart cap. Communication will be subject to cryptography at the highest level of security, which ensures the integrity, confidentiality and authenticity of information during its transmission between the mentioned devices. We will use Diffie-Hellman key exchange [8]. The Diffie-Hellman cryptographic key exchange protocol represents the generation of a common crypto-key locally on both sides of the client and server (that is, "smart caps", phones and cloud servers when exchanging data packets containing information about EEG signals and generated photos) without the key is ever exchanged online, which directly excludes the risk that the key may become publicly available during communication interception.

The first step of data protection involves identifying sensitive data to determine the scope of protection. Subsequently, we plan to implement strong cryptographic algorithms, such as AES, to encrypt data before storing it in the database. Decryption keys will be securely stored and strictly managed to prevent unauthorized access. Integrating encryption into the application and enforcing strict access controls to the database would further enhance data security. Additionally, we propose regular monitoring and auditing of data access activities, as well as frequent updating of security mechanisms to maintain a high level of security. These proposed measures aim to ensure the integrity, confidentiality and availability of data on our server, in line with best practices for information protection [9].

The application implemented on the smartphone has the task of collecting relevant data from the Smart EEG device and the smart watch, after which it sends this information to the cloud server for further analysis and storage. Additionally, in a situation where the smart watch detects a Rapid Eye Movement (REM) phase of sleep, the mobile application will initiate the Smart EEG device wake-up. This procedure is carried out with the purpose of starting the recording of brain impulses (EEG) during the specified stage of sleep. The application will be designed with the aim of adapting it for use on Android and iOS operating systems. Implementation of the application for Android users will be realized through the use of the Java programming language, while for iOS users the Swift programming language will be used. The development environment for implementing the application can be set up through the Eclipse platform, while Adobe XD is provided for creating the user interface. In order to facilitate the user experience and provide support, itis planned to direct users to the Learning Management System (LMS) platform. This platform will provide additional means for training and educating users about the functionalities and proper use of the application.

A smart watch is an electronic device equipped with sensors and various functionalities, designed to monitor and analyze various aspects of the user's sleep. It includes an accelerometer for detecting changes in the speed and direction of movement during the night period, as well as a gyro-sensor for precisely tracking the orientation of the watch in relation to the user's position. Along with heart rate monitoring sensors, the device provides data on physiological parameters during sleep. In addition, the presence of a light monitoring sensor enables the detection of changes in the environment, which is used to analyze the sleep cycle. The smartwatch is equipped with a long-life battery to enable continuous monitoring throughout the night. Water resistance is implemented as a feature that improves the durability of the device in contact with water. With Bluetooth connectivity, the device enables data synchronization with a smartphone. The accompanying sleep tracking app allows users to analyze the various stages of sleep, in detail, including light, deep, REM, as well as periods of wakefulness. Users are given the option of setting alerts or reminders, contributing to improving sleep quality. Through an ergonomic and attractive design, the smartwatch has been conceptualized to ensure comfort during nighttime wear, thus encouraging uninterrupted sleep monitoring and obtaining relevant data about the user's night's rest.

Conclusion

Ultimately, systems for recording dreams using EEG technology, such as Dreamento, Dreem 2, and the DREAM database, can be compared to the system developed in this research, which utilizes a smart EEG cap, smartphone, and watch that detect the REM phase. While Dreamento and Dreem 2 enable precise monitoring of brain activity and sleep stimulation at home, our system offers additional functionality through integration with a cloud server and a database of processed signals obtained from a larger group of participants. The key advantage of our system is the ability to create video recordings in the form of images from the database using AI, enabling a more detailed insight into dream content and their neural correlates, significantly expanding the possibilities for dream research and analysis. This research, involving image display, EEG signal recording, and analysis, aims to deepen our understanding of the relationship between visual stimuli and brain activity during dreams. By integrating artificial intelligence and electroencephalography (EEG), this approach offers a novel perspective on neurological processes during sleep. The fusion of these techniques allows for the identification of specific brain patterns associated with different types of dreams or emotional experiences during sleep, potentially paving the way for personalized medicine and tailored therapeutic interventions based on individual characteristics of brain activity during dreams. Moreover, the application of artificial intelligence in interpreting EEG signals and generating video recordings accelerates the analysis process, providing insights that extend beyond neuroscience to fields such as psychology, medicine, and computer science. These investigations not only contribute to our understanding of dreams but also hold promise for the development of diagnostic tools for sleep disorders and neurological conditions. However, further research is recommended to expand the sample size, explore different types of images, and develop more advanced algorithms for EEG signal analysis during dreams. Additionally, integrating user feedback through applications to enhance data collection and storage in databases requires careful consideration of data validity. Despite the current limitations in system stability, rapid advancements in technology and artificial intelligence offer the potential for greater reliability and feasibility in the future. Overall, this research underscores the importance of multidisciplinary collaboration among experts in neuroscience, psychology, computer science, and medicine to explore new frontiers in the study of dreams and brain activity during sleep, ultimately advancing our understanding and application of this fascinating realm of human experience.

References

[1] Kandel, E.R., Schwartz, J.H., & Jessell, T.M, Principles of Neural Science, McGraw-Hill, New York,2000.

[2] Gonzalez, R.C., Woods, R.E., Digital Image Processing, Pearson Education, Upper Saddle River,2008.

[3] Kales, A., & Hughes, R.D., Sleep and Brain Activity, MIT Press, Cambridge,1970.

[4] Nam, C.S., & Nijholt, A., An Overview of Basic Concepts and Clinical Applications ,EEG-Based Brain-Computer Interfaces, Springer, London,2010.

[5] Goodfellow, I., Bengio, Y., & Courville, A., Deep Learning. MIT Press, Cambridge,2016.

[6] Foster, D., Generative Deep Learning, O'Reilly Media, Sebastopol,2019

[7] Langr, J., & Bok, V., GANs in Action, Manning Publications, Shelter Island,2019

[8] Stallings, W., Principles and Practice, Cryptography and Network Security, Pearson Education, Upper Saddle River,2010.

[9] Menezes, A.J., van Oorschot, P.C., & Vanstone, S.A., Handbook of Applied Cryptography, CRC Press, Boca Raton,1996

[10] Created with Microsoft Copilot

[11] Medical computer systems, https://mks.ru/en/products/neorec-cap/

[12] Krigolson Lab, https://www.krigolsonlab.com/research.html

[13] Medium, https://levelup.gitconnected.com/generative-adversarial-networks- unlocking-the-power-of-artificial-creativity-beginners-guide- 7353a70a8709