بسم الله الرحمن الرحيم

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تم رفع هذه الرسالة بواسطة / حسام الدين محمد مغربي

بقسم التوثيق الإلكتروني بمركز الشبكات وتكنولوجيا المعلومات دون أدنى مسئولية عن محتوى هذه الرسالة.

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Ain Shams University
Faculty of Computer & Information Sciences
Scientific Computing Department

Development of Robust Electrooculography (EOG) Based Human Computer Interface

Thesis submitted as a partial fulfillment for the requirements for the degree of
Master of Science in Computer and Information Sciences

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A Thesis submitted to Scientific Computing Department, Faculty of Computer and Information Science, Ain Shams University, in partial fulfillment of the requirements for the degree of Master of science in Scientific Computing.

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Abstract

Recently, the increase in the number of patients with motor disabilities has become a noticeable phenomenon all over the world. The reasons for this increase are due to the emergence of many diseases that cause motor nerves to atrophy and thus prevent the motor limbs from performing their vital role. This injury extends to all parts of the body and causes complete paralysis and only the neurons that control eye movement survive. Hence, patients do not have a way to communicate with their surrounding environment except through the movement of their eyes.

The human-computer interface (HCI) has emerged and become a new communication way and support tool for these patients. It allows a communication between the user and the computer that depends on the analysis of voluntary, controlled bio-signals to choose a specific action, execute, and display it on the computer screen. HCI systems are based on determining eye movement directions from Electrooculogram.

An electrooculogram (EOG) records eye movement as signals produced from variation in the polarity of the nerve of the eye. EOG recording is performed by a set of electrodes placed horizontally and vertically on the controlling muscles of the eye. The relationship between the electrooculography signals and eye movement is linear. The waveform of the electrooculography signal is completely in line with the eye movement, so it is easy to analyze and identify.

This thesis proposes a HCI writing system based on classifying EOG signals by a proposed deep learning model. This system helps all patients with diseases that cause severe motor disability and paralysis in all their limbs. In addition, it provides them with a new way of communicating with their external environment without always needing a companion. The proposed system detects six different directions of eye movement: up, down, right, left, center, and blinking, in addition, using them to select letters, write messages from a virtual keyboard, and vocalize them as well.

The vertical and horizontal EOG signals are filtered from noise using a second-order band-pass filter. Two different approaches have been considered to classify the signals. The first approach depends on extracting the statistical and morphological features from the filtered signals and concatenating them in a final feature vector that represents an entry for six machine learning classifiers. The six classifiers are Linear Discriminant Analysis (LDA), Support Vector Machines (SVM), Multinomial Logistic Regression (MLR), K Nearest Neighbor (KNN), Decision Trees and Naïve Bayes (NB). The second approach relies on concatenating the horizontal and vertical filtered EOG signals into a vector as input to five deep learning models: Convolutional Neural Network (CNN), VGG Network, Inception Network, Residual Network, and ResNet-50 Network. Experiments have been conducted on two datasets: public small dataset and PSL-IEOG2 dataset

which is a large dataset collected by us using the PSL-IEOG2 device dedicated to measure eye signals.

The experimental results reveal that the inception deep learning model outperforms all the other considered models and traditional classifiers with an overall accuracy of 98.8%. The user interface has designed consisting of four forms: the first is the opening form and displays all the possibilities offered, the second is a virtual keyboard for writing messages, the third includes the daily activities which patients are accustomed to use, and the last one contains the trending news circulating on the most famous news sites. Finally, the processing time to complete a selection in any form is only one second.

List of Publications

1) Reda R, Tantawi M, Shedeed H, Tolba M F. Analyzing Electrooculography (EOG) for Eye Movement Detection. The International Conference on Advanced Machine Learning Technologies and Applications (AMLTA2019). Springer International Publishing, Cham. 2020;179-189.

2) Reda R, Tantawi M, Shedeed H, Tolba M F. Eye Movements Recognition Using Electrooculography Signals. Proceedings of the International Conference on Artificial Intelligence and Computer Vision (AICV2020). Springer International Publishing, Cham.2020;1153:490-500.

3) Reda R, Tantawi M, Shedeed H, Tolba M F. Development of Electro-oculogram Based Human Computer Interface System Using deep learning. Bulletin of Electrical Engineering and Informatics, Indonesia.2021. (Q3, SJR 0.251)

4) Reda R, Tantawi M, Shedeed H, Tolba M F. Developing a Method for Classifying Electro-Oculography (EOG) Signals Using Deep Learning. The International Journal of Intelligent Computing and Information Sciences (IJICIS). Egypt.2021.

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List of Abbreviations

Abbreviation	**Stands for**
ALS	**A**myotrophic **L**ateral **S**clerosis
ADC	**A**nalog to **D**igital **C**onverters
Ag/AgCl	**A**r**g**entum **C**h**l**oride
ANN	**A**rtificial **N**eural **N**etwork
AR	**A**uto-**R**egressive
CWT	**C**ontinuous **W**avelet **T**ransform
CNN	**C**onvolutional **N**eural **N**etwork
DAQ	**D**ata **A**c**Q**uisition
DC	**D**irect **C**urrent
DWT	**D**iscrete **W**avelet **T**ransform
ECG	**E**lectro**C**ardio**G**ram
EEG	**E**lectro**E**ncephalo**G**ram
EMG	**E**lectro**M**yo**G**ram
EOG	**E**lectro**O**culo**G**ram
FN	**F**alse **N**egative
FP	**F**alse **P**ositive
FFT	**F**ast **F**ourier **T**ransform
FFNN	**F**eed **F**orward **N**eural **N**etwork
FT	**F**ourier **T**ransform
GBS	**G**uillain-**B**arre **S**yndrome
HCI	**H**uman **C**omputer **I**nterface
HMI	**H**uman **M**achine **I**nterface
ILSVRC	**I**mageNet **L**arge **S**cale **V**isual **R**ecognition **C**hallenge
IG	**I**nformation **G**ain
KNN	**K** **N**earest **N**eighbor
LDA	**L**inear **D**iscriminant **A**nalysis
LSTM	**L**ong **S**hort **T**erm **M**emory
ML	**M**achine **L**earning
MLR	**M**ultinomial **L**ogistic **R**egression
NB	**N**aïve **B**ayes
NN	**N**earest **N**eighbor
PAP	**P**eak **A**mplitude **P**osition
PAV	**P**eak **A**mplitude **V**alue
PC	**P**ersonal **C**omputer
PSL-DAQ	**P**hy**S**io **L**ab **D**ata **A**c**Q**uisition
PSL-IEOG2	**P**hy**S**io **L**ab **I**ndustry **E**lectro**O**culo**G**ram **2**

PSD	**P**ower **S**pectral **D**ensity
PDQ	**P**roduct **D**ata **Q**uality
RNN	**R**ecurrent **N**eural **N**etwork
STFT	**S**hort **T**erm **F**ourier **T**ransform
SVM	**S**upport **V**ector **M**achines
TDNN	**T**ime **D**elay **N**eural **N**etwork
TN	**T**rue **N**egative
TP	**T**rue **P**ositive
USB	**U**niversal **S**erial **B**us
VAP	**V**alley **A**mplitude **P**osition
VAV	**V**alley **A**mplitude **V**alue
VGG	**V**isual **G**eometry **G**roup
WT	**W**avelet **T**ransform

Chapter 1

Introduction