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Real-Time BCI System Design to Control Arduino Based Speed Controllable Robot Using EEG

Springer

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Preface

Brain–computer interface (BCI) systems have always been of great use to needy paralyzed patients having the ability to provide control over any desired device. The present world calls for the need of a strong assistance system to help physically impaired people perform any anticipated task without human aid. This book proposes such a system which has the ability to perform desired actions in real time and give the impaired person a facility to move a robot in any specified direction. The system acquires the neurally impaired patient's brain signals using a SIMULINK-based model and uses their thoughts and expressions to interact with an Arduino-based speed controllable robot. It has future prospects of being implemented as a complete moving apparatus along with the patient without the involvement of any physical activity. The system is based on a graphical user interface (GUI) that will determine the direction of movement of the robot, a self-developed algorithm which preprocesses the obtained data from EMOTIV EPOC neuroheadset and then classifies the data using artificial neural network, and finally an algorithm to process the gyroscope signals using Kalman filtering to develop a mouse emulator, thereby giving the user ability to interact with the developed GUI as mentioned.

The design of mouse emulator which imitates the operations of a mouse uses the data obtained from the gyroscope embedded in the neuroheadset. The information obtained by the gyroscope in real time is used to control the relative position of the pointer which points to various operations to move the robot in the designed GUI. Hence, the proposed BCI system will perform the following primary functions:

i. The first algorithm extracts DWT coefficients from raw EEG signals and then reduces redundancy using principal component analysis (PCA). The extracted data is then used to train a neural network which has the ability to classify any preprocessed input EEG data. The dominant frequency band is generally taken under consideration for further processing.
ii. The second algorithm acquires velocity data from an embedded gyroscope. This data is then Kalman-filtered to remove unwanted jitter and noise. After conversion into displacement by integration, the final data is used to move the

pointer as per the user's head movement. Thus, the user can control the mouse movement as well as click the screen whenever he/she wants to, with the help of classified data obtained from neural networks.

iii. The third part includes programming the Arduino board in order to make it capable of receiving and interpreting data successfully. The board then receives control commands from the computer to move the robot in various directions.

The above applications are integrated to control a GUI, developed in MATLAB which displays all possible movements of an Arduino-based robot. Hence, the movements of the robot can be controlled by the user by concentrating on GUI and clicking on whichever motion he/she wants. The computer communicates with the Arduino board by serial communication.

Coverage and Organization

In this section, the overview of this manuscript, which is mainly structured into five chapters, has been presented.

Chapter 1 presents a brief layout of BCI covering BCI's history, some information, BCI applications of the present and future, core concepts on BCI, and finally the objective. Chapter 2 depicts an outline of the human brain also including the fundamentals of EEG recording. Chapter 3 is a detailed portrayal of the algorithms used and to be used probably in the field of BCI. Chapter 4 is a representation of the work done in detail. Starting with the acquisition, this chapter also focuses on EEG data classification module, gyroscope signal processing, and then the final implementation of control of the robots depicting the processes of interfacing and execution.

The final Chap. 5 is a comparative overview of the complete book and the final conclusions drawn from various annotations.

Pilani, India

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About the Authors

Swagata Das is pursuing her Ph.D. in biological systems engineering at Hiroshima University, Japan, having completed her M.Tech. in electronics design and technology, for which she received a gold medal at Tezpur Central University, Assam, India. She was also awarded gold medals by His Excellency Late Dr. A. P. J. Abdul Kalam, ex-President of India, and Shri. Kapil Sibal, ex-Union Minister of India, for her exceptional performance in academics at NERIST, Itanagar, India. Her research interests include electronics applications of mathematical modeling and brain–computer interface. She has published her research work in Springer and IEEE proceedings.

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Abbreviations

AAR	Adaptive auto regressive
AD/HD	Attention-deficit/hyperactivity disorder
ADC	Analog-to-digital converter
AIS	ASIA Impairment Scale
ASIA	American Spinal Injury Association
ALN	Adaptive logic network
ANC	Activity of neural cells
ANFIS	Adaptive neuron-fuzzy inference system
ANN	Artificial neural network
API	Application programming interface
AR	Auto regressive
BCI	Brain–computer interface
BGN	Bayesian graphical network
BLRNN	Bayesian logistic regression neural network
BMI	Brain–machine interface
BOLD	Blood oxygenation level-dependent signals
BP	Band power
CAR	Common average referencing
CGM	Conjugate gradient method
CMRR	Common mode rejection ratio
CMS	Common mode sense
CNP	Cortical neural prostheses
CNS	Central nervous system
CSPs	Common spatial patterns
CSSD	Common spatial-subspace decomposition
CSSP	Common spatio-spatial pattern
CSV	Comma-separated value
DAP	Deep anal pressure
DBI	Direct brain interface
DIL	Dual inline package

DRL	Driven right leg
DWT	Discrete wavelet transform
ECoG	Electrocorticogram
EDF	European data format
EEG	Electroencephalography
EMG	Electromyography
EML	EmoComposer Markup Language
EOG	Electrooculography
ERD	Event-related desynchronization
ERPs	Event-related potentials
ERS	Event-related synchronization
FIRNN	Finite impulse response neural network
fMRI	Functional magnetic resonance imaging
fNIRS	Functional near-infrared spectroscopy
GDNN	Gamma dynamic neural network
GMMs	Gaussian mixture models
GUI	Graphical user interface
HCI	Human Computer interface
HMM	Hidden Markov model
ICA	Independent component analysis
IDE	Integrated development environment
IOHMM	Input–output HMM
ISP	In-system programmer
kNN	k-nearest neighbors
LAT	Local averaging technique
LDA	Linear discriminant analysis
LIS	Locked-in syndrome
LVQ	Learning vector quantization
MAP	Maximum a posteriori
MLP	Multilayer perceptron
MNF	Maximum noise fraction
MNs	Multiple neuromechanisms
MRPs	Movement-related potentials
MSE	Mean square error
NIRS	Near-infrared spectroscopy
NLI	Neurological level of injury
OVR	One versus the rest
PCA	Principal component analysis
PE	Processing elements
PNS	Peripheral nervous system
PSD	Power spectral density
RBF	Radial basis function
RFLDA	Regularized Fisher's linear discriminant analysis
RMP	Resting membrane potential
ROM	Range of motion

SCG	Scaled conjugate gradient
SCP	Slow cortical potentials
SDK	Software development kit
SL	Surface Laplacian
SNR	Signal-to-noise ratio
SPS	Samples per second
SSVEP	Steady-state visual evoked potential
SVD	Singular value decomposition
SVM	Support vector machine
TCP/IP	Transmission control protocol/Internet protocol
TDNN	Time delay neural network
TTD	Thought translation device
VEPs	Visual evoked potentials
XML	Extensible Markup Language

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