ISO/IEC TR 27599

Edition 1.0 2025-05

TECHNICAL REPORT

Information technology – Brain-computer interfaces – Use cases

ICS 35.200

ISBN 978-2-8327-0400-4

ISO/IEC TR 27599:2025-05(en)

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INFORMATION TECHNOLOGY – BRAIN-COMPUTER INTERFACES – USE CASES

FOREWORD

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ISO/IEC 27599 has been prepared by subcommittee SC 43: Brain-computer interfaces, of IEC technical committee JTC 1: Information technology. It is a Technical Report.

The text of this Technical Report is based on the following documents:

Draft	Report on voting
JTC1-SC43/134/DTR	JTC1-SC43/152/RVDTR

Full information on the voting for its approval can be found in the report on voting indicated in the above table.

The language used for the development of this Technical Report is English.

This document was drafted in accordance with ISO/IEC Directives, Part 2, and developed in accordance with ISO/IEC Directives, Part 1, and the ISO/IEC Directives, JTC 1 Supplement available at www.iec.ch/members_experts/refdocs and www.iso.org/directives.

INTRODUCTION

Brain-computer interface (BCI) has unique technical aspects, and there are few similar international standards or technical reports.

This document provides a collection of representative use cases of brain-computer interface applications in a variety of domains. The current document reflects contributions and discussions by ISO/IEC JTC 1/SC 43 experts and liaison members.

In particular, SC 43 performed research on the standardization requirements of BCI, and this document presents the conclusions. BCI technology is gradually being applied to many real-world application fields, including smart environments, medical and health, education, industrial control, and gaming. In the future, this technology will bring new changes and developments in more fields. Therefore, to ensure that BCI technology can better benefit humans, it is important to carry out standardization research work on the technology, which mainly focuses on the standardization of BCI technology, ethics, and safety.

INFORMATION TECHNOLOGY – BRAIN-COMPUTER INTERFACES – USE CASES

1 Scope

This document provides a collection of representative use cases of brain-computer interface (BCI) applications in a variety of domains: proposed medical and health, industrial controls, smart environment, etc.

This document can be used for the development of potential standards, and it is valuable for a better comprehension of BCI.

This document is also helpful for BCI industries and products that provide support for communications among interested parties and stakeholders.

This document is applicable to all types of organizations (e.g. commercial enterprises, government agencies, not-for-profit organizations).

2 Normative references

ISO/IEC 8663, *Information technology – Brain-computer interfaces – Vocabulary*[1]

3 Terms and definitions

For the purposes of this document, the terms and definitions given in ISO/IEC 8663 and the following apply.

ISO and IEC maintain terminology databases for use in standardization at the following addresses:

- IEC Electropedia: available at https://www.electropedia.org/
- ISO Online browsing platform: available at https://www.iso.org/obp

3.1
minimally invasive BCI
minutely invasive BCI
invasive brain-computer interface paradigm or system which requires a surgical procedure but with a low risk of infection and a minimal contact or disruption of neural tissue and vasculature

Note 1 to entry: The electrodes can be placed outside the dura mater (epidural).

3.2
implanted sensor
implantable sensor
sensor which is placed inside the body after surgical incisions, providing accurate in vivo physiological measurement in humans and other animals

[1] Under preparation. Stage at the time of publication: ISO/IEC CDV 8663:2024.

3.3
classifier
trained model and its associated mechanism used to perform classification

[SOURCE: ISO/IEC TS 4213:2022, 3.1.2]

3.4
target stimulus
stimulus to which subjects in a test or procedure must respond

Note 1 to entry: Among many stimuli, a person selects the one to which he or she responds.

Note 2 to entry: Adapted from reference [1].

3.5
external stimulus
stimulus that originates from outside the organism and that does not rely on the subject's reaction

Note 1 to entry: External stimulus can be an electrical, optical, auditory or mechanical signal, cue or event.

3.6
motion-onset visual evoked potential
mVEP
neural potential that occurs when motion-related stimuli are attended visually

Note 1 to entry: Adapted from reference [2].

3.7
deep brain stimulation
DBS
neurosurgical technique that uses implanted electrodes and electrical stimulation to treat neural disorders

Note 1 to entry: Deep brain stimulation is the most performed surgical treatment for Parkinson's disease.

3.8
functional electrical stimulation
FES
activity-based intervention that extrinsically activates the neuromuscular system below the level of the lesion, inducing plasticity of the neuromuscular and central nervous systems

3.9
mental state
mental property
mental condition
set of characteristics of a person's affective and psychological mode or status

3.10
vegetative state
clinical condition of complete unawareness of the self and the environment, accompanied by sleep–wake cycles, with either complete or partial preservation of hypothalamic and brainstem autonomic functions

Note 1 to entry: Adapted from reference [3].

3.11
minimally conscious state
clinical condition of severely altered consciousness in which minimal but definite behavioural evidence of self or environmental awareness is demonstrated

Note 1 to entry: This definition is taken from reference [4].

3.12
awareness detection
method to explore and measure the quality or state of the subject's consciousness

Note 1 to entry: Usually, awareness detection is performed by evaluating vegetative state and minimally conscious state.

3.13
biometrics system
system that enables a person to be identified and authenticated through capturing the recognizable, verifiable, unique, and specific physiological data

3.14
cursor control
brain-computer interface system that presents a user with a movable item used to mark a position and translates the moving direction by interpreting the user's neural activities

3.15
shared control
<system> characterized by the use of both user control and an automation component

Note 1 to entry: A shared control BCI system uses both the direct input from the user by interpreting neural activities and assistance from artificial intelligence technology.

3.16
online analysis
type of brain-computer interface (BCI) classification procedure that is performed immediately following data acquisition, translating neural activities into BCI commands

Note 1 to entry: Online analysis must be used in real-time BCI applications.

3.17
offline analysis
offline training
type of brain-computer interface classification or training procedure performed at a separate time after data acquisition is completed

3.18
classification accuracy
metric for evaluating classification models in brain-computer interface prediction

Note 1 to entry: Accuracy equals the number of correct predictions over the total number of actual predictions.

3.19
information transfer rate
ITR
evaluation metric devised for brain-computer interface systems that determines the amount of information that is conveyed by a system's output per unit time

Note 1 to entry: Adapted from references [5] and [6].

4 Abbreviated terms

ANN	artificial neural network
AR	augmented reality
BCI	brain-computer interface
BMI	brain-machine interface
CRS-R	coma recovery scale – revised
CSP	common spatial pattern
CT	computed tomography
DBS	deep brain stimulation
DOC	disorders of consciousness
ECoG	electrocorticogram
EEG	electroencephalography
EER	equal error rate
EMG	electromyogram
EOG	electro-oculogram
FBCCA	filter bank canonical correlation analysis
FDA	Food and Drug Administration
FES	functional electrical stimulation
FPGA	field-programmable gate array
fMRI	functional magnetic resonance imaging
fNIRS	functional near-infrared spectroscopy
iEEG	intracranial electroencephalography
I/O	input or output
ITR	information transfer rate
LFP	local field potential
LiDAR	light detection and ranging
MI	motor imagery
MRI	magnetic resonance imaging
mVEP	motion-onset visual evoked potential
NIRS	near-infrared spectroscopy
PCA	principal components analysis
RAA	reading assessment apparatus
SEEG	stereoelectroencephalography
SoC	system on chip
SSVEP	steady-state visual evoked potential
VR	virtual reality

5 Data analysis of BCI use cases

5.1 List of use cases

Table 1 shows summary information for each of the 32 use cases, including name, application domain, and status. Subclauses 7.3 to 7.8 provide details on each use case, listed by application domain.

Table 1 – List of use cases

No.	Title	Application domain	Status
1	Passive brain-computer interface (pBCI)-based adaptive automation (AA)	Smart environment	Proof of concept
2	BCI-based smart ward system	Smart environment	In operation
3	Brain-machine interface (BMI) enabled assistive communication system	Smart environment	Proof of concept
4	Monitoring and early warning technology for the fitness of special operations personnel based on EEG signals	Smart environment	In operation
5	Minimally invasive implanted closed-loop brain-computer interface system	Medical and health	Proof of concept
6	Neural state dependent closed-loop deep brain stimulation	Medical and health	In operation
7	Invasive brain cursor control system	Medical and health	Proof of concept
8	Multi-site closed-loop neurostimulation for clinical seizure modulation	Medical and health	Prototype
9	AR-based brain-computer interface for upper limb rehabilitation	Medical and health	In operation
10	Brain-controlled robot grabbing to assist daily life	Medical and health	In operation
11	Rehabilitation training system based on MI-BCI	Medical and health	In operation
12	Brain-computer interface in diagnosis and treatment of depression	Medical and health	In operation
13	The M-score: motor function assessment using BCI	Medical and health	Proof of concept
14	Shen Gong robotics: BCI-driven rehabilitation training system	Medical and health	Proof of concept
15	Music intervention based on brain-computer interface system	Medical and health	Prototype
16	Wearable seizure onset detection system	Medical and health	Proof of concept
17	Clinical diagnosis and prognosis in patients with disorders of consciousness (DOC)	Medical and health	In operation
18	An adaptive AR display to improve situational awareness using BCI in stressful and fatigue-inducing situations	Medical and health	In operation
19	Portable brain-related symptom screening, monitoring and surveillance system using non-invasive electroencephalograph	Medical and health	In operation
20	Portable brain-related symptom management system using non-invasive brain stimulation	Medical and health	In operation
21	Automated seizure detection and prediction	Medical and health	Proof of concept
22	Near-infrared BCI intervention in patients with stroke	Medical and health	Proof of concept
23	Fusion of multi-modal fNIRs and EEG information for motor imagery classification	Medical and health	Proof of concept
24	BCI controlled exoskeleton with seven degrees of freedom for assistance and rehabilitation applications	Medical and health	Proof of concept
25	BCI controlled wheelchair for assistance and rehabilitation	Medical and health	Proof of concept
26	Reading assessment apparatus (RAA)	Learning, education and training	Proof of concept
27	BCI-based biofeedback for accelerated learning	Learning, education and training	In operation
28	Brain-computer interface in aerospace applications	Industrial controls	In operation
29	T-Drone	Industrial controls	In operation

No.	Title	Application domain	Status
30	Cognitive regulation based on brain-computer interface game	Gaming	Prototype
31	The MindGomoku: an online P300 BCI game	Gaming	Prototype
32	Non-invasive brain signal-based biometrics system	Security and authentication	Proof of concept

5.2 Application domains

Figure 1 describes the distribution of use cases by application domain. Six application domains – security and authentication, smart environment, medical and health, learning, education and training, industrial controls, and gaming – were considered as target domains for the use cases.

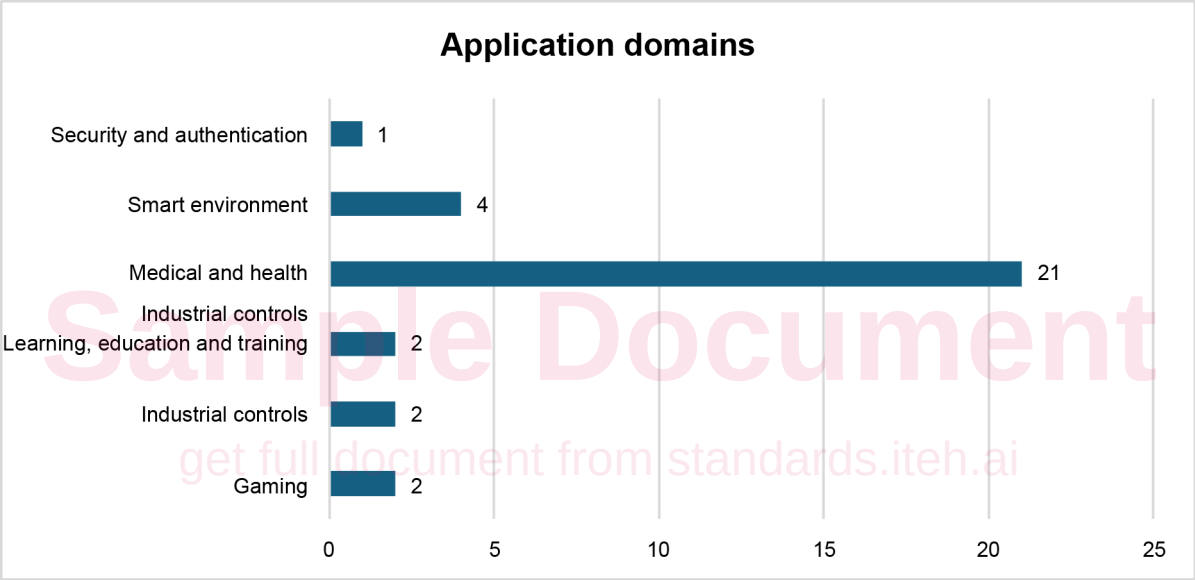

Figure 1 – Application domains of all the collected BCI use cases

5.3 Data characteristics and processing methods

5.3.1 General

BCI mainly identifies users' intentions by analysing the acquired brain electrical signals. There are two main methods for collecting brain electrical signals: invasive and non-invasive. The advantage of invasive methods is that the accuracy of electrical signals is high, but this method has certain surgical risks. Relatively speaking, non-invasive methods are more convenient and safer.

5.3.2 The characteristics of EEG

Electroencephalography (EEG) signals, as a kind of bioelectrical signal, directly reflect the simplest brain activity. Compared with other physiological electrical signals, EEG signals have the following five characteristics.

a) They are very weak, measured in microvolts (μV), with frequencies ranging from 0,5 Hz to 100 Hz. EEG signals are easily contaminated with noise, such as power-line interference, electro-oculogram (EOG), and electromyogram (EMG).

b) The EEG signals exhibit strong randomness and instability, which means that the statistical characteristics of the EEG are independent of time.