

BRAIN & MIND interface

"If the brain was simple enough to be understood - we would be too simple to understand it!"

Abstract

This paper presents a concise human-being description (using Human Specification Language HSL¹) with a special attention to the brain and mind including interfaces between them.

Two conceptual interfaces having different nature but functionally integrated are specified.

BCI is more technical and deals with "hidden" physiological events while BMI (Brain Mind Interface) is focused on "visible" (e.g. psychological) information. The medical context should be considered here not in the category of advanced medical science but as a standard knowledge used for illustrative purposes.

Keywords

brain, mind, brain2mind interface, BCI, HSL, human specification language, neural network

Introductory remarks

A brain is the most important, interesting and mystic organ of human-being. Researchers have been trying to explore this "territory" by means of brain-computer-interfaces (BCI) and artificial neural networks. A BCI is currently defined as "a system that measures central nervous system (CNS) activity and converts it into artificial output that replaces, restores, enhances, supplements, or improves natural CNS output"[3].

1. HSL Human Specification Language (basics)

Notation

<!...>	comment	ppppXxxx	item Xxxx with prefix 'pppp'
< >	container	UUUU.xxxx	xxxx belongs to UUUU
<def > </def>	start end of definition	& /	conjunctions 'and' 'or'
• located in, » «	outside interface	Σ	neural network, Ξ layer(I,M,O) <input,med,out>
≡>	mapping or multitracks	↔	bidirectional passive unary relation 1:1
{.[(..)] .}	nested list of items	→	forward unary passive relation
optional, ⊥ blocked, isolated		<=>	complex or many to many active relations
xxxx(..)	name of list	<=, =>	backward, forward active relations
: equivalent :: belongs to		@dark	unknown, to be obtained, discovered
= value # number of		..	more, ... much more
¥ output Φ function		?	to be verified
process(actions(events)) .e.g.pr(ac1,ac2,ac3)		s(ev1,ev2,ev3, ..)	<!sequential flow of events>
ac(ev1,ev2,ev3) <!action-sequence of events>		p(ev1,ev2,ev3, ..)	<!parallel flow of events>
		pr(s(ac1,s(ev1,ev2,ev3),ac2(p(ev4,ev5,ev6),(ev7,ev8)))	<!mixed flow>

Human-being is an "open system which maintains a constant state while the matter and energy which enter it keep changing"[7 p.11] . A brain is the commander of such behavior. "Cogito ergo sum". Our mind is based on our brain, but the quality of both is changeable depending on genetic code, health's state, breeding, education etc.

¹ This paper is based on HSL Language DOI: 10.13140/RG.2.2.36330.62409

<def subject HUMAN>

class1[animals.mammalia.primates.homidae.homo-sapiens]
class2[nation.ethnic-group.person]
ENV[WORLD,CONTINENT,COUNTRY,REGION,SITE]<!environment>
ENV.legal<!Legal acts,resolutions,decisions>
ENV.cultural[tradition,history,education,religion,ideology,art,mass-media]
ENV.geogr[homeAddress,company/school]

<def PERSON>

object.nfo[id,sex,birth-data]
invariables[id,sex,birth-data]
homeaddress[country,site,street,house,flat]
sex(male/female/x)
body[(brain,liver,kidney,joints,..) weight,height,eyes-colour,defects]
mind[wisdom(thinking,reasoning,learning,recognizing,communication-skill),
knowledge,...])
family[gentree,parent,child,son,daughter,
grandSon,grandDaughter,granMa,granPa]
complexEmotion[love,hate,satisfaction,frustration,aggression,enjoyment/pleasure,anger,..]
elementaryEmotion[hunger,thirst,chills,pain,..]
complexPsych[fear-of-insupport,regression,inferiority,persecution]
habit,hobby,profession,
health[measures,physical-examinations,illness-history],
role[advisor,consultant,manager,patron,partner,customer,
supervisor,participator,owner,supplier,
user,analyst,designer,programer,operator] <!plus 'role' in kernel>
appearance depends on,assisted by,belongs to,matched/matches,
relations<!plus relations in kernel>
relates to,used by,uses,not used,misused,abused,
state[active,inactive,dormant,suspended,aborted,idle,lost,dead,
homeless,retired,married/divorced/single,ignored]
place[point, area,everywhere,nowhere]
life-space[psychological,social,educational,professional,financial]
behaviour<!flow of processes of the object >
behaviour.rational[selfrealization,need,satisfaction]
behaviour[marriage,friendship,career,illness,aging]
genotype,phenotype
olh:=[birth,aging-curve,social-events,health_illness-events,
educ-events,job-events,critical_events,death]<!object-life-history>
cluster{<! cluster is a global feature estimated on the base of several characteristics
i.e. output of classifier, class>
[self,profile/type,attitude,leadership,ability,
extraversion,anxiety,independence,healthState,
lifeStyle,creativePotential,happiness,BipolarPersonality]
self[self-identity,self-assesment,self-sentiment,self-esteem,
self-regard,self-reliance,self-control,
self-image,self-extension,self-structure]
leadership[assertive,creative,facilitative,independent,
stable,permissive,leadership(Style,Potential]
ability[toughMinded/openMinded,creative,fast/slow,
toleratesDisorder/perfectionistic,grounded/abstracted,
improving own learning,problem solving, IQ,]
need[biological(food,medical,emergency,rescue, coping),
cultural,psychological(love,esteem,selfrealization),
financial-resources,security]
}

BipolarPersonality[Warmth(reserved/warm),Reasoning(concrete/abstract),
 EmotionalStability(emotional/stable),Concillation(conciliatory/aggressive),
 Dominance(deferential/dominant),Liveliness(serious/lively),
 Openness(extraversive/introversive),Tension(relaxed/tense),
 Rule-Consciousness(expedient/rule-Conscious),SocialBoldness(shy/socially-bold),
 Sensitivity(utilitarian/sensitive),Vigilance(trusting/vigilant),
 Abstractedness(grounded/abstracted),Privateness(forthright/private),
 Apprehension(self-assured/apprehensive),
 Self-Reliance(group-oriented/self-reliant),
 OpennessToChange(traditional/open-to-change),
 Perfectionism(tolerates disorder/perfectionistic)]

2.Brain

The brain is defined as "a self-organizing, self-modifying organ with learning, memory, and categorization capabilities that recruits our sensory and motor systems in order to identify patterns in, model, and modify the external world".[1-p.114]

<def BRAIN>

brainId(<personId&/biologicalId>)

mainpart[forebrain(cerebrum(hemisphere,thalamus,hypothalamus),midbrain,hindbrain]

area[cortical-region,nucleus(clump/layer)<! e.g.region of gray matter>]

part[cerebral-cortex,basal,dienceph,brainstem,cerebellum,hippocampus,spinal-cord]

cerebral-cortex {lobe[frontal,parietal,occipital,temporal(hippocampus, ..)]}

cortical-region[primary-visual,entorhinal,inferior-temporal,orbitofrontal,
 lateral-prefrontal,inferior-parietal,..]

cortex-functional-area[visual,sensory,tactile,auditory, ..]

cortex-multifunctional-dispersed_area[limbic(hippocampus,amygdala,thalamus,hypothalamus)...]

somatosensory-system[subsystem1(touch,pressure,pain,tickle,itch,vibration,temperature,
 proprioception,kinesithesis),subsystem2(sight,hearing,taste,smell)]

detail-part[neuron,synapse,receptor,unpaired-electron,neurotransmitter,glia-cell,..]

neuron {[nucleous(mithochondria,membrane,cytoplasm,vesicle,perycarion),
 myelin-sheath,schwann-cell,axon,dendrite],
 input(electrosignal,chemical-pharmacological,natural-signal(light,sound,pressure))]
 form(multipolar,bipolar,unipolar),creation-type(primary,new-born,»mirror²)]}

brain-basic-function[sensory(vision,hearing,smell,touch,...),
 mental(association,speech,language-comprehension,coordination,...),
 motor(eye-movement,voluntary-movement, ..)
 hidden(intuition,premonition,..)]

brain-complex-function[consciousness(self,..),cognitive-activity,wisdom,intuition,..].

cognitive-activity(attention coordinating,decision making,movement selection)

mapping[engine \Rightarrow view, view \Rightarrow engine]

view {natural[electrophysiological,biochemical,psychophysical,..]

conceptual(semantic,psychological,mathematical,ontological,..]}

engine[thinking,emotions,info-retrieval,memorizing,communication,..]

communication[comm-layer[stream[message(carrier,protocol,pattern),signal]]]

signal(electrical,chemical,natural),communication-layer(single,multichannel)

neurotransmitter(acetylcholine,glutamate,y-aminobutyric-acid,glycine,
 oxytocin,vasopressin,endorphins,..)<!electrochemical transmitter>

diseases[dementia-senilis,alzheimer,parkinson,tourette-syndrome,huntington,stroke,
 aneurysm,concussion,delirium,atrophy,obsessive-compulsive-disorder,.
 sclerosis(multiplex,lateralis),hydrocephalus,amnesia,ataxia,split-brain),...]

</def brain>

² "copy" from outside (during communication with another person)

3. Neural networks

Neural network approach is a fundamental tool for investigating the brain behaviour. Mapping some biological brain neural networks into artificial ones could be done successfully while "screening" the whole brain (or dispersed areas like limbic system) to the assembly of interconnected networks is a very complex task due to complexity and embedded plasticity (a brain changes the pattern of wiring between neurons in response to inputs and experience). Many neural networks are interdependent and this is, for example, in case of spoken language and motor control.

A complexity of brain biological networks is very high (almost hundred billions of neurons & trillions of connections) and activity of them may be classified as a biological computation. Connections are made by activation of neural circuits having required potential (LTP - long term potentiation) and they are triggered by many events (emotion, narrative speech, stress, psychotherapy, medications ...). Active neuron is alive neuron - for the neuron making connection or being connected is a question "to be or not to be".

Examples of biological neural networks are: nerve tracts connecting left and right cerebral hemispheres, the left and right temporal lobes, visual area located (occipital lobe) with retina and thalamus.

Artificial neural networks could roughly simulate biological ones using mathematical formulas. They work in multilayer mode and consist of input layer, hidden middle layers and output layer. Output is formed mostly by learning technology and nonlinear activation function from a set of many inputs.

ANN have been used in medicine in many cases e.g. for diagnose nerve disorders, Parkinson's and Huntington diseases, heart disease and to forecast the action of various healing treatments. [12].

```
<def neural-network>
  neural-network.category[brain-biological/artificial]
  neural-network-layer.type{[single-layer(perceptron,adeline),multi-layer],[feedforward,recurrent]}
  neural-network-specific-type
    [convolutional,learning-vector-quantization,fuzzy,gaussian-kernel&radial-basis-function,
     bayesian-logistic-regression,gamma-dynamic,finite impulse response,hopfield,kohonen, ... ]
  neural-network.parameters[layers(input,intermediate,output)(hidden/visible),
    connection-between-layers(backpropagation,...),variables,expected-values,weights,weight-rules,
    learning{[method(supervised,unsupervised,reinforced)],
    density,#layer(#node,#glia-cell),changeability-level]
  brain-neural-networks(corpus-callosum,visual,memory,basic-functions,retina, language, social,..)3
  Σcorpus callosum[∃left cerebral hemisphere <=> ∃right cerebral hemisphere]
    <!essential for integration of cognitive and emotional functioning>
    <!if severed => (split-brain): conflictual behavior(i.e.hands discord),epilepsy,anxiety,
      affective-disorders,psychosis,alexithymia,disruptions of the self.. >[10]
  Σvisual[∃retina(∃photoreceptors,∃ interneurons,∃ganglion-cells)
    => ∃thalamus(messages) => ∃visual area •occipital lobe]
    <! puts together the color, motion, orientation, depth information to "see" the image>
  Σmemory(∃hippocampus<=>∃parahippocampal )
  Σbasic-functions(∃medulla<=>∃spinal-cord) <!swallowing,heart rate,breathing>
  Σsocial(∃medial-prefrontal-cortex<=>∃posterior-superior-temporal sulcus)
  Σlanguage{left-hemisphere[lobe(temporal,occipital,parietal) Φconvergence(auditory,visual,sensory)]
    Ξ=>(wernicke's-area,broke's-area,..) [right-hemisphere Φ feature-of-speech(emotional,prosodic)]}.
</def neural-network>
```

³ list of brain neural networks described in this work is based on published sources.

4. Brain interface

```
<def basic BCI> <!Brain Computer Interface>
  category[(unary,hybrid),(med-standard-device,biologically-interfaced-device(PSbased,..))]
  hybrid(multi-brainpatterns,multi-sensory-stimuli,multi-modal-signals,multi-intelligent.).
  object-view[SourceObject,stream(message),ReceivingObject]
  functional-view[signal-acquisition,preprocessing(artifact-removal,filtering),
    feature-extraction,classification, <device action>]
  SourceObject[personId[cortical-region[layer]/electrode-placement-code]]
  ReceivingObject[medical-device /& computer]
  {stream(<source><receiver/device>),[message[signal[impulse]],flow-type]
    parameters[standard(type,id, encryptionCode,securityCode,timeStamp)
      extended(timeInterval,duration,populationShape,dynamics,dispersion,
        measureUnit,accuracy,disturbance)]
    trigger(event/ERP,time,demand, )... }
  <!stream is one/multi-channel collection of messages directed to one receiving device>
  <!message is one-channel sequence of signals issued at a given time>
  <!signal is a set of electrical impulses that flows on groups of active neurons>
  message[cp,data]<!cp:comm:communication protocol>
  signal(EEG,MEG,fMRI,DTI,NIRS,EOG,EMG,sEMG,ECG,EcoG,..)
  signal-type(magnetic,electro-magnetic,electrical,chemical,fluid/blood-flow),
  electricalSignal(potential(SCP,ERP(P300,..))
  cp(tcp/ip,udp,i2c,spi,can,hart,ethernet,wifi,rf,bluetooth,nfc,satellite,6lowpan,
    mqtt,zigbee,coap,z-wave,uart,modbus,device-embedded, BCI-p,...)
  flow {type[cerebral-fluid,cerebral-impulse,blood-flow,...]
    activated/triggered by <.> with <value> at <time-point>/when <condition>
    finished at <> with <...> when <.> }
</def basicBci>

<dev DEVICES> <!devices used in BCI>
  type[medDevice /& medComp],id,name,
  signal-aquisition-method,comm(embedded,external),software(embedded,external),
  technical-info(manufacturer,first-instal-year, wear%,configuration-settings,
    reliability(OEE (MTTF,MTBF,MTTR),operating-instruction/protocol ...),
  medical-info[diseases,effects(direct-effects,side-effects..),contraindications,
    precautions,patient-state(before,after)],
  risk-of-use(risk-classes),conformity(directives-standards,technical-requirements),
  signal-aquisition-method[sensor(electrode(type),CT(X-ray),MRI(magnetic-resonans),
    fMRI(mri+blood flow,oxygen level),DTI(mri+water molecules),EEG(electrical waves)...),
    invasive/semiinvasive/noninvasive),
    cortical-region/point-of-contact/placement-code],
  medDevice.function(recording,diagnosis,monitoring,treatment,alleviation,...),
  medDevice-category[stationary,mobile(bluetooth,wifi,internet),stand-alone(touch,cable)],
  medDevice[triggered-by(event,time,demand, ...),link-mode(<=>,<= , =>,<← , → )],
  mobile-medDevice[smartphone,wearables(smartwatch,smartband,headset,...)],
  stationary-medDevice-name(EcoG,EEG,fMRI,fNIRS,INR,MEG,PET,MRT, ...),
  embedded-software(pacemaker,noise-artifact-removal, frequency-filtering, ...),
  potential(ERP(P300..),SCP,TTD,...),
  noise-artifacts(movement-related,eye-blinking,heart-related,...) ,
  medComp(super-comp,mini-comp,micro-comp,bio-comp,bio-hybrid-comp...)
</def Devices>
```

5. Brain to mind interface

The "mind" is a tool for thinking, deciding, and remembering [2], that could be looked at as a neuro-information processing device [4], not represented physiologically by signals but by the flow of information i.e. therefore has not been analyzed as the biophysical matter presented in BCI.

A mind is closely related to consciousness. This relation is of tricky type: "mind is part of consciousness but consciousness transcends mind" [11]. The question "where are situated the mind and consciousness in a brain?" may be evasively answered that locations are several cortical and subcortical regions acting in conjunction.

Mind capabilities are clearly expressed by such personal features as:

- wisdom: right assessment, choice of solution,
- ability: tough minded/open minded, creative, fast/slow, tolerates disorder/perfectionistic, grounded/abstracted, improving own learning, problem solving, IQ,
- . - assertiveness, creativeness, independence, stability, leadership.....

<def BMI><!/brain to mind interface-advanced BCI>

brain \Rightarrow mind-functions <!/brain to mind mapping>

lobes of the cerebral cortex(somatosensory-cortex,..)<=>

[process sensory information(smell,taste,sight,sound)]

hippocampus¶hippocampal<=>[memories(form,organize,consolidate,retrieve)]

hypothalamus <=>[emotions(hunger,thirst,chills,pleasure,pain,..),..]

<!/connector between the endocrine and nervous systems>

prefrontal dorsolateral cortex <=> consciousness

corpus callosum <=> unity of consciousness

orbitofrontal cortex & limbic system<=> "self" identity

limbic system <=> emotions

mind-functions \Rightarrow brain <!/reverse mapping>

process sensory information(smell,taste,sight,sound)<=>lobes of the cerebral cortex

memories(form,organize,consolidate, retrieve)<=>hippocampus¶hippocampal

endocrine&nervous systems connection<=>hypothalamus

consciousness<=>[prefrontal dorsolateral cortex,

corpus callosum(unity of consciousness),orbitofrontal("self" identity)]

Locations of emotions and a "self" (including consciousness) are spread over the brain and are not easy to indicate. A limbic system placements concern several areas in the cerebrum (cingulate gyrus, orbito- frontal cortex, parahippocampus) as well as a number of sub-cerebral structures such as portions of the thalamus & hypothalamus, the nucleus accumbens (in the basal ganglia), the septal nuclei and the amygdala.[5]

The consciousness is a very complex function represented by following cognitive information flows: associative, reflexive, perceptual, emotional, verbal, analytic.

mapping(<engine \Rightarrow view> /& <view \rightarrow engine>)

engine[thinking,emotions,info-retrieval,memorizing,intuition(trust,love,hate),
communication,total-brain,.....]

view {natural[electrophysiological,biochemical,psychophysical,medical,..]

conceptual(semantic,psychological,mathematical,ontological,..)}

<def>**emotionEngine** => **psychologicalView**
emotionEngine[frontalLob,hypothalamus,limbic-system,..]
psychologicalView[love,hate,satisfaction,frustration,agression,enjoyment,anger,
fear of insupport,regression,inferiority,persecution] </def>

<def>**totalEngine** => **medView** <!total engine refers to the whole brain>
totalEngine(brainArea/neural network-area,disease-brain-pattern)
medView(disease(neurodegenerative,neurological,..),injury,
neurodegenerative(dementia/alzheimers,parkinsons,huntingtons,..),
neurological(autism-spectrum,tumor,migraine,multiplesclerosis,epilepsy,stroke,..))</def>

To create brain pattern of disease is a complex task. For example "pain disorders" spreads out on lateral&orbital prefrontal cortex, anterior cinglate, cerebellum, right fusiform gyrus, pons, parahippocampus, right dorsolateral cortex, anterior cingular cortex, midbrain, anterior insula, nucleus accumbens and more...[10].

<def>**totalEngine** =>/ → **ontologicalView**
totalEngine(brainStructure,brainContents)
ontologicalView(brainId,brainAging(neurons(#dead,#born,#total)),diseasesHistory,
brainVolume-dynamics(curve,...),brainUsage) </def>

<def>**totalEngine** =>/ → **energeticView**
totalEngine(brainStructure,brainContents)
energeticView(brainId,power-consumption vs aging,power-supply-disturbances) </def>

<def>**totalEngine** => **mindView** <!total Engine refers to the whole brain>
totalEngine(neural networks,mind-pattern)
mindView[(active/passive),(medical,logical,semantic,psychological,mathematical,ontological)]
mindEngine[thinking,emotions,info-retrieval,memorizing,intuition(trust,love,hate),
communication,..] </def>

</def BMI>

Concluding remarks

Human-being is very much complicated object and there are many things (one of them is a brain) to investigate using advanced theory and technology (neuroengineering, cognitive computing). An approximative approach, based on rough or fuzzy sets, could probably help for example in the case of vaguely defined neural networks.

Many problems (e.g. consciousness) remain a great mystery.It would be great if using simplified componential models led to finding factors of general importance and thus diminished the need for a detailed mapping of the whole brain to one complete neural network.

"It is humbling and more than a little frightening to realize that we rely on what may be the most complex structure in the universe with little knowledge of how it works." (Louis Cozolino)

References

- [1] Ch.S. Nam, A. Nijholt,F.Lotte"Computer Interfaces Handbook:Technological & Theoretical Advances " CRC Press 2018
- [2] Krawczyk H.,Targowski A."Wisdom in the Context of Globalization and Civilization" Cambridge Scholars Publishing 2019
- [3] Wolpaw J.,Wolpaw E. "Brain-Computer Interfaces: Principles and Practice" Oxford University Press, 2012.
- [4] Henriques Gregg "What Is the Mind" www.psychologytoday.com/us/blog/theory-knowledge/201112/what-is-the-mind
- [5] Best Ben "An overview of neural networks" "Neurophysiology and Mental Function" www.benbest.com
- [6] "Brain Facts" Society for Neuroscience 2018
- [7] Johnson R.A.,Cast F.E.,Rosenzweig J.E. "The Theory and Management of Systems" McGraw-Hill Book Co 1967
- [8] Society for Neuroscience "Brain Facts" 2018
- [9] Mitchell M., Ubiquity symposium: biological computation. Ubiquity, Volume 2011 Issue February, February 2011
- [10] Cozolino L.J. The Neuroscience of Psychotherapy W.W.Norton&Co 2009
- [11] <http://operationmeditation.com/discover/mind-vs-brain-vs-consciousness/>
- [12] E.Xhumari,P.Manika "Application of artificial neural networks in medicine" CEUR Workshop Proceedings vol.1746 2016