Comptes rendus de l'Acade'mie bulgare des Sciences, Vol 72, No6, pp.796-802

COMPUTERS vs HUMAN BRAIN

Pencho Marinov, Kiril Boyanov

ABSTRACT

The article discusses some issues related to the information capabilities of the human brain. Based on the fact that the measure of unit information is bit, the volume of information that can be stored in the brain and its capacity for keeping and reproducing text and audio information are evaluated and calculated. An analysis of the computer potentials to model the process of recognizing images that take place in the human brain has been performed. A hypothesis that real-time modelling of these processes is difficult to realize with the current parameters of the computers is presented.

Key words: human brain, image processing, transfer of information, information processing, measurement of quantity of information, information capabilities of the human brain

DOI: 10.7546/CRABS.2019.06.12

Topic: ENGINEERING SCIENCES

Go BACK

Print this abstract

Full Text

Доклади на Българската академия на науките
Comptes rendus de l'Académie bulgare des Sciences

Tome 72, No 6, 2019

ENGINEERING SCIENCES
Systems theory

COMPUTERS VS HUMAN BRAIN

Pencho Marinov, Kiril Boyanov

(*Submitted on March 12, 2019*)

Abstract

The article discusses some issues related to the information capabilities of the human brain. Based on the fact that the measure of unit information is bit, the volume of information that can be stored in the brain and its capacity for keeping and reproducing text and audio information are evaluated and calculated. An analysis of the computer potentials to model the process of recognizing images that take place in the human brain has been performed. A hypothesis that real-time modelling of these processes is difficult to realize with the current parameters of the computers is presented.

Key words: human brain, image processing, transfer of information, information processing, measurement of quantity of information, information capabilities of the human brain

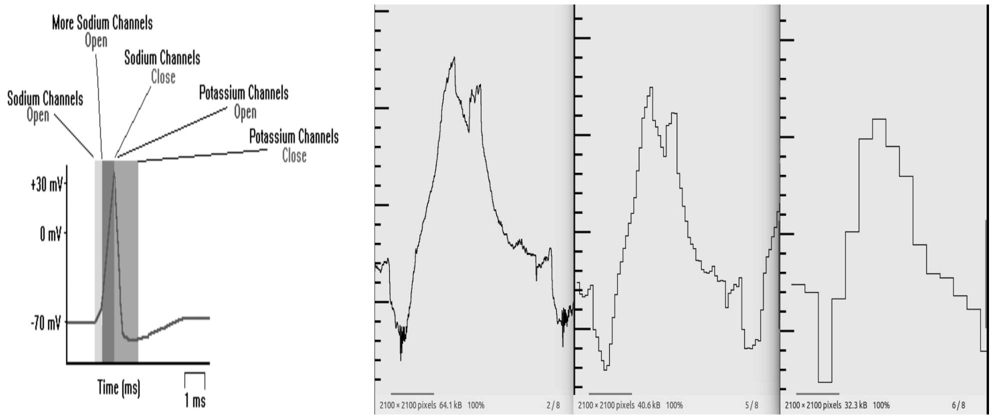
1. Introduction The human brain has always been interesting from a research point of view. Over the past centuries many people have studied its abilities [[4]]. They have been tempted to explain its exceptional capabilities, for both memorization and processing information.

Today, this issue continues to be addressed by scientists from various fields – neurobiologists, biologists, neurosurgeons, computer scientists, and others. One of the major human brain projects in Europe is funded at 1.5 billions.

Is it possible to assess the information potentials of the brain, taking into account two important parameters – the volume of the stored information and the processing speed. Certain assumptions can be made that their likely maximum values are taken into account, and it is conditionally assumed that the measure per unit of information is a bit introduced by Claude Shannon last century.

This research has been partially supported by the Bulgarian National Science Fund under grant No BNSF-DN12/6.

DOI:10.7546/CRABS.2019.06.13



(A) (B)

Fig. 1. (A) Neuron function; (B) Data records with three kinds of sampling: 30 kHz, 3 kHz, 500 Hz

It is possible to model or evaluate the brain's information capabilities for some of the basic functions that it performs: memorizing texts and their reproduction, remembering music and playing it, memorizing images and reproducing them. These are some of the main instances that people use in their social activity.

Assuming that the main carriers of the information are the neuronal cells that communicate with each other through synapse connections, build neural networks and have the property of storing, processing and transmitting information, we can quantify the volume of memory information within maximum limits.

According to some authors [5], the brain contains approximately 86 billion of neurons, with 69 in the brain and 16.3 in the cortex. Considering the Neuron's connections to his colleagues valued at 7000, a rough estimate can be made for the maximum stored information. Figure 1(A) shows a characteristic function of a neuron when it passes from an excited to an inactive state, which gives us the prerequisite to assume that it has two states – "1" and "0". The mode of transmission of the information is analogous [3,6], but since the anode signal can be represented by discrete values, the adopted measure "bits" for the information is appropriate. Assuming that each neuron remembers one bit of information, we get about 100 billion or in bytes (B) (1 B is 8 bits), roughly 10 gigabytes (10^9 B). If the mechanism of memory includes synapse links, we will get an estimate of just over 10 terabytes (10^{12} B).

The frequency of sampling was very important for data processing and Fig. 1(B) shows data records for 30 ms with three kind of frequencies.

According to research, the information that accumulates worldwide grows extremely fast and in the coming years is expected to reach 20 000 exabytes (EB) (1 EB = 10^{18} B).

It should be noted here that, according to some authors, the storage of information may be performed by a group of neurons or by a group of neurons and the corresponding synapses.

Since a maximum amount of information is sought in the event that a bit is presented by several neurons, the measured information will be smaller, i.e., the search for the maximum volume by using the number of neurons gives a relatively good estimate for the upper limit. Some authors report synapse links as memorable, and then the estimate is significantly greater than 10 gigabytes, as with these assumptions of several thousand connections, the total maximum volume reaches a range of terabytes (10^{12} B) and even petabytes (10^{15} B). In any case, even a 10 gigabyte estimate gives us an idea of the vast amount of information that the human brain can store.

2. Comparison Rough evaluation of this memory through a page in standard format (30 rows $\times 66$ characters) is in the range of 5 000 000 printed pages. Assuming a character is encoded with a 1 B, then one page is represented with 2 kilobytes. Obviously, such a volume of information is not contained in the human brain. If the extraordinary abilities of genius writers and musicians are taken into account, the volume of the active information they use at the maximum threshold can reach up to several tens of megabytes. The natural conclusion is that there is a significant amount of free memory that allows the brain to build new connections, to ensure a certain reserve and security of the information it stores and processes. It should be taken into consideration that an estimate of the amount of memory associated with the emotional characteristics of the brain is not considered.

An interesting question is about exchanging information and processing textual information, respectively [[1]]. Let a talented actor remember 100 pages with 300 words pure text on a page. Assuming that for 1 second two words of 5 characters are spoken and assuming that there is an average of 300 words on the page, then $(300 : 2) \times 100 = 15\,000$ seconds or 4.1 hours. For this time, $15\,000 \times 80$ or 1.2 megabits will be handed over. Two words each 5 characters on average are encoded with 80 bits. The volume of the transmitted information will be about 150 kilobytes (1.2 Mb = 150 KB).

Let us look at the sound transmission by selecting an example with The "Minute" Waltz (Op. 64, No. 1) of Frederic Chopin, which takes about a minute. Basically 50 piano keys are used, and assuming 8 bits are coded for each key plus one bit for a trigger or not, but we are allocating 10 bits to encode the volume, then we will have 19 bits information encoding one note. The very rough evaluation wizard contains 730 notes, so we get that 240 bits are transmitted per second (bps). The volume of the 4.1 hours audio data will be in the range of 3.4 megabits or 425 kilobytes. Here the data is appropriately selected to show that if a sound is used, a larger amount of transmitted information is obtained, i.e. if we use sound, we can transmit more information for a certain amount of time. Naturally "storm" or "marine waves" will perform better and faster through sound and the accuracy will be greater when using sound instead of speaking.

Let us look at a 106×60 cm (approximately 48$''$ diagonal for 16:9 aspect ratio) screen when transmitting images and assuming a resolution of 1920×1080 pixels or about 2 megapixels. If we specify 8 bits per pixel to encode brightness, colour, and colour density (3 Bpp), we will get 6.6 megabytes of data. And the most talented artist can not literally produce a copy of a picture of these dimensions in real-time without watching it, because his memory can not store such volume of information.

Some researchers estimate that the eye is an organ that allows a quantity of information to be received in the order of 7.2 megabits per second or about 900 kilobytes per second. The fact that our eyes perceive such a huge amount of bits suggests that television and other visual observation devices are the fastest sources for receiving large volumes of information. With the mass introduction of television and computers, the visualization capabilities also increase. The flow of information increases significantly, implying the need for rapid processing.

The fact is that a gifted artist can easily reproduce Faust of Goethe or parts of it, a gifted musician can play 32 Beethoven's sonatas or any of them. In these cases, the amount of information is in the order of tens of megabytes. Gifted artist can hardly reproduce with any colour shades a picture of Leonardo or Rembrandt. The information here is gigabytes. This suggests that the problem is either in the large amount of information that can not be reproduced over a certain period of time through the sensory organs, or in the associative search in the specified memory fragments. Due to the large amount of image recognition information, the brain works following specific algorithms. Modelling of computer recognition processes can give a rough idea of the workings of the human brain.

Assuming that computer modelling compares the colours for each pixel, the computer's running time can be calculated separately for certain assumptions. It is assumed that the computer comparison takes one or two microoperations in the machine, which is a bit rough approximation.

The maximum speed P [Ops] (Ops is the number of elemental operations per second), which can be achieved at the current level B is limited by the maximum frequency f [Hz] (assuming that the time for 1 operation is $T = 1/f$)

$$f = \frac{c}{\lambda} = 10^{17} \text{ Hz},$$

where $\lambda = 3 \times 10^{-9}$ m is the shortest wave approaching the molecular level, $c = 3 \times 10^8$ m/s is the speed of light.

In these assumptions, the maximum speed is

$$T = \frac{1}{f} = 10^{-17} \text{ s} \quad \text{and} \quad P = 10^{17} \text{ Ops}.$$

With modern computers it is much less than the order of

$$T = \frac{1}{f} = 5 \times 10^{-10} \text{ s} \quad \text{and} \quad P = 2 \times 10^{9} \text{ Ops}.$$

Note. In the notes below $\mathcal{O}\left(10^k\right)$ is understood $C \times 10^k$, where C is a constant from 0.1 to 100, depending on the complexity of the object being perceived.

With a 1920×1080 pixel screen, we have 2 037 600 or approximately 2 mega pixels (2 M). Let us say we want to make a comparison of a real world image with the one that would be stored in the human brain. Each pixel stored in memory is compared to each pixel in the picture.

Let us assume that the time of comparison of 1 pixel (modelling of a pixel) is equal to one microoperation, i.e. B 10^{-17} s for the optimistic option B 10^{-9} s for the pessimistic option. We have several options to estimate the time taken to capture two images (i.e. compare them) – the actual image and what is in the memory.

(a) **pessimistic – optimistic:** For 1 pixel we have 24 bits = 3 Bytes, and $2^{24} = 17 \times 10^6$ values. Without resize, but with denoising, edge detection, proximity assessment for whole image needed $\mathcal{O}\left(10^{12}\right)$ operations or $\mathcal{O}\left(10^{-5}\right)$ seconds (This is with optimistic speed 10^{17} Ops);

(a) **pessimistic – pessimistic:** For the same number of operations, the time is $\mathcal{O}\left(10^{3}\right)$ (for pessimistic computer speed variant);

(a) **optimistic – pessimistic:** With resizing and other image-manipulation operations, including a smaller depth (bits per pixel [bpp]) for example 10^2 smaller size (number of pixels), 10^4 smaller depth (8 bpp instead of 24) the time is $\mathcal{O}\left(10^{-3}\right)$ seconds;

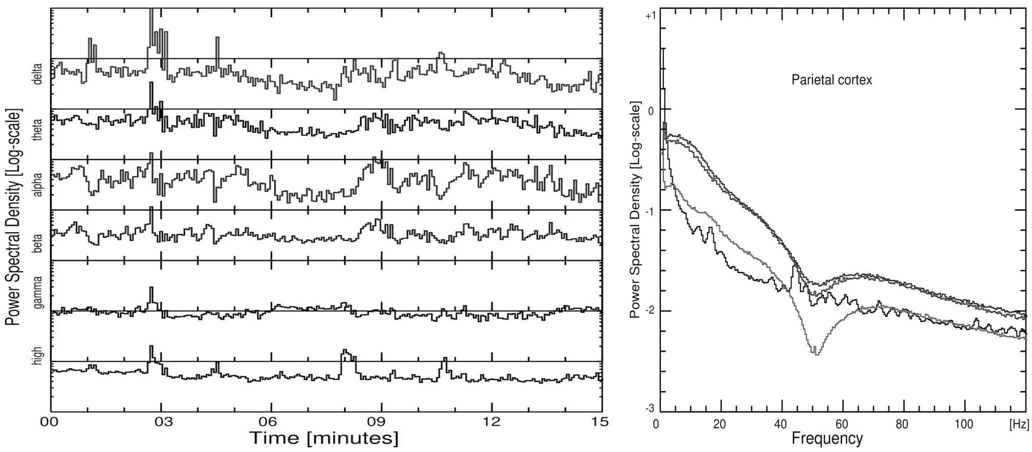
(a) **optimistic – optimistic:** With optimistic number of operations and optimistic speed of computer we receive $\mathcal{O}\left(10^{-11}\right)$ seconds.

In computer processing, the theoretical evaluation reaches so many differences as they are carried out additional activities related to: (a) remove noise (denoising); (b) change size (resize); (c) subdivision of subfields (segmentation); (d) find contours (edge detection); (e) proximity appraisal (proximity assessment). The aforementioned activities are highly dependent on the complexity of the image.

3. Discussion. The above calculations show that the capabilities of modern computers to simulate various brain models designed to reveal its mechanisms for identifying and processing information are limited in real time.

The evolution we see in the development of new connections in the brain alters the patterns of research. Currently, scientists have chosen two approaches to brainstorming.

1. Simplification of models using known mathematical tools: partitioning, using known techniques for image recognition, overlay, rotation, etc. It can be



(A) (B)

Fig. 2. (A) Amplitudes in time for six group frequencies – δ-, θ-, α-, β-, γ-, *high*-waves, for one channel, one experiment; (B) Averaged specters for four different experiments

expected that by increasing computer speeds or computers on new principles (e.g. quantum) it will be possible to simulate real-time precision models, to describe the processes of processing information and its storage in the brain.

2. Process investigations by implanting electrodes into the brains of experimental animals. The resulting reductases are interpreted using similarity tools.

The worm's nervous system is in the order of several thousand cells, and we can identify a particular cell and identify it in another worm of the same species – for example, the rash, that is, the worm (see [7]). Rainy worms have isomorphic brains or, in fact, we have a worm.

Experiments with the implantation of electrodes in the brain of rats, see Fig. 2 (presumably their brain is similar to human but with less neurons), allows us to obtain certain information through EEG. It is related to the spectrum and frequency of electromagnetic signals, the time for activation of one or another area in the brain, and the characteristics of the inverse signal. Surgical separation of certain areas in the rat brain allows, for example, the possibilities of reserving the information (for example, in orientation). Analysis of these results is the subject of other publications [2,8].

Viewed everywhere, the complexity of the signals is large and requires a different representation for a fuller understanding of their nature. A short description for two ways of representation of results after data processing of EEG signals: amplitudes was presented in logarithmic scale; Fig. 2(A) corresponding of data only from one channel, for one experiment, 15 minutes time-interval, six group frequencies cover up to 120 Hz; Fig. 2(B) shows four averaged specters (for different experiments) but in details for all frequencies up to 120 Hz.

4. Concluding remarks. The philosophical question that physicists wonder about the possible mechanisms accurate models in quantum mechanics is if it can be assumed to also apply to the human brain.

Is it possible to achieve a precise model of the processes of processing and storing information in the brain through the brain of the researcher? Does the model change during the study and what tools are needed for that? If this is a computer, what should its performance be to capture the processes that develop in the brain. And the natural next question is: whether the researcher's 'brain' will be able to interpret the information received within the time frame of the observation process?

REFERENCES

[1] Boyanov K. (2012) On the Measurement of Quantity of Information on Speech, Sound and Image and their Link with the Information Processing. In: Proc. Joint Int. Conf. on Human-Centered Computer Environments HCCE 2012, pp. xviii-xix, ACM ISSN 978-1-4503-1191-5, Aizu-Wakamatsu, Japan.

[2] Chekalarova J., L. Kortenska, P. Marinov, K. Boyanov (2016) Comparative power spectrum analysis of EEG activity in spontaneously hypertensive and Wistar rats in kainate model of temporal model of temporal model of epilepsy, Brain Res. Bull., **124**, 62–75.

[3] Lee W. C. A., H. Huang, G. Feng, J. R. Sanes, E. N. Brown et al. (2006) Dynamic remodeling of dendritic arbors in GABAergic interneurons of adult visual cortex, PLoS Biology, **4**(2), e29, `doi:10.1371/journal.pbio.0040029`.

[4] López-Muñoz F., J. Boya, C. Alamo (2006) Neuron theory, the cornerstone of neuroscience, on the centenary of the Nobel Prize award to Santiago Ramón y Cajal, Brain Res. Bull., **70**(()4–6), 391–405.

[5] `https://en.wikipedia.org/wiki/Neuron`, `https://en.wikipedia.org/wiki/List_of_animals_by_number_of_neurons`.

[6] Llinás Rodolfo R. (2014) Intrinsic electrical properties of mammalian neurons and CNS function: a historical perspective, Front. Cell. Neurosci., 2014-11-04, **8**, art. 320, PMCID: PMC4219458, DOI: 10.3389/fncel.2014.00320.

[7] Hubel D. H. (1971) Communication with Extraterrestrial Intelligence. In: Proc. First Soviet-American Conference on CETI (ed. C. Sagan), Bayrakan Observatory, Yerevan, USSR, 5–11 Sept 1971, 78.

[8] Tchekalarova J., D. Atanasova, L. Kortenska, N. Lazarov et al. (2019) Agomelatine alleviates neuronal loss through BDNF signaling in the poststatus epilepticus model induced by kainic acid in rat, Brain Res. Bull., **147**, 22–35.

Institute of Information and Communication Technologies
Bulgarian Academy of Sciences
Acad. G. Bonchev St, Bl. 25-A
1113 Sofia, Bulgaria
e-mails: `pencho@parallel.bas.bg`,
`boyanov@acad.bg`