University of Telecommunications and Post
Sofia, Bulgaria

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Brain-Computer Interface for Control and Communication with Smart Mobile Applications

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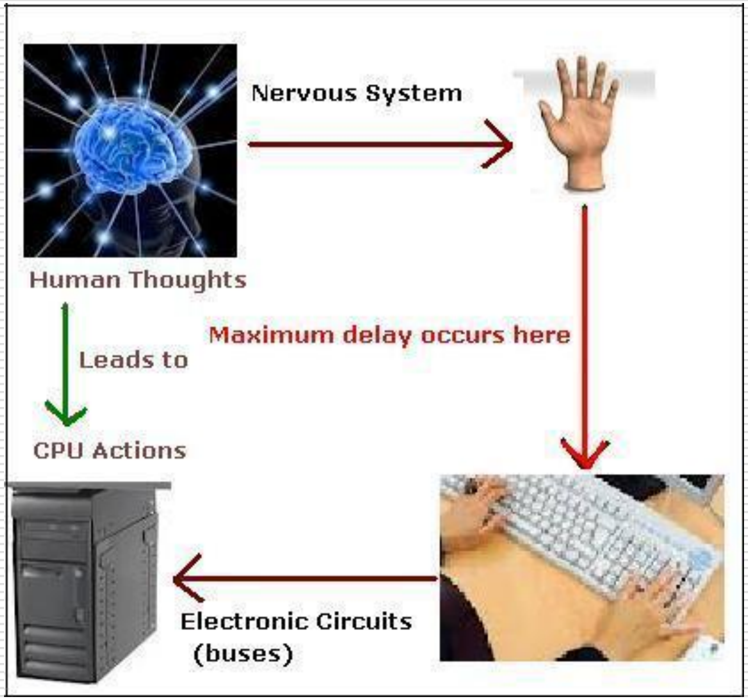
HUMAN - COMPUTER INTERACTION

The considered Human-Computer Interaction (HCI) system is based on Brain-Computer interface (BCI) which use measured Electroencephalography (EEG) activity or other electrophysiological measures of brain functions as new non-muscular channels for control and communication with smart devices and smart mobile applications for disabled persons. The research aims developing of technology for communication with smart mobile applications, based on processing of recorded electrophysiological signals at execution of different mental tasks.

HUMAN-COMPUTER INTERACTION



- Human brain decides the instruction for delivering to thinking activity;
- This decision, from human-brain, is transfer to human peripheral(s) by nervous system;
- From human peripheral(s), this decision is transferred to computer peripheral;
- From computer peripheral the decision, which is now computer command is transferred to CPU (computer brain);
- CPU executes the task.

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HUMAN - COMPUTER INTERFACE

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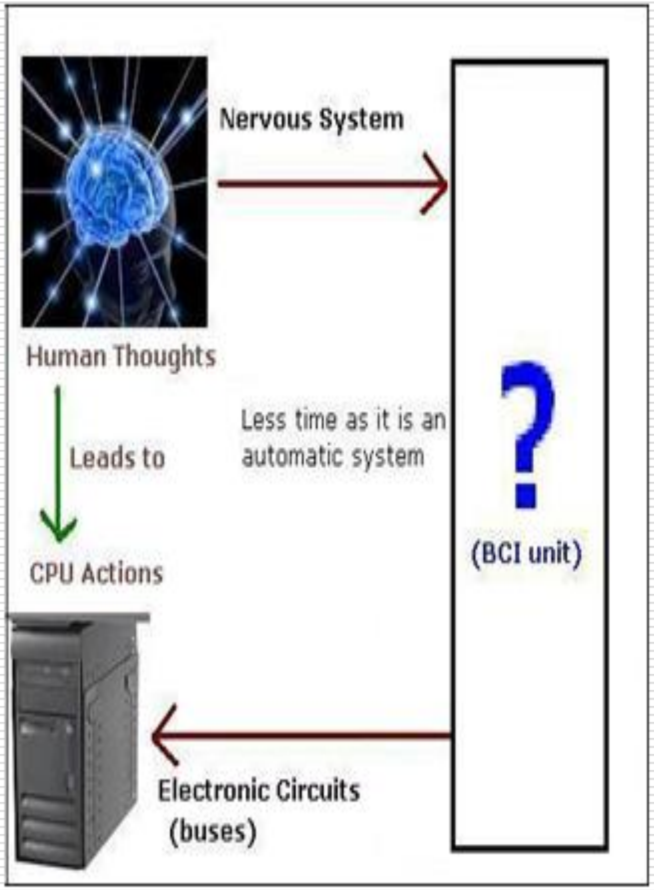

- The time taken by human brain to decide on the first step and CPU to execute the instruction on the last step is almost negligible . The rest steps are a medium which-just bridging a gap between human thinking process and CPU understanding process.
- If we can somehow bridge this gap via some automatic means, then a brain-computer interface will convert human brain thoughts directly into computer brain instructions or executing programs.

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BRAIN-COMPUTER INTERFACE

The interface between numan brain and computer, called Brain–Computer Interface (BCI) is a Human-Computer Interaction (HCI) technique where register brain signals directly convert into computer commands.

BCI implementation:

- computer games, which can be made more attractive, useful and effective with BCI;
- embedded systems;
- using BCI in operating machines;
- medical industry - biggest area of BCI application etc.

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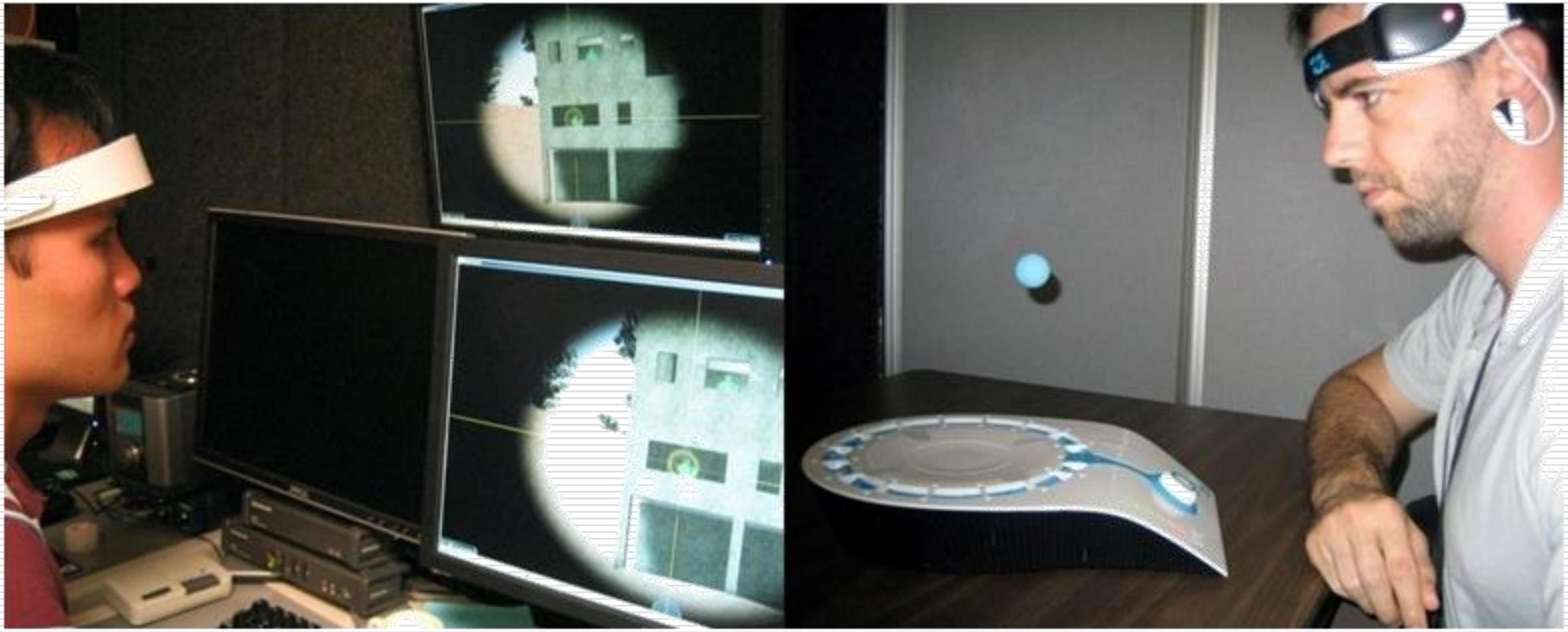
BRAIN-COMPUTER INTERFACE



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BRAIN-COMPUTER INTERFACE

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BCI system for communication with smart mobile applications

- **Step 1:** ***Thinking in Brain*** - when something is to be done a thought is developed into the brain which leads to development of a neuron potential pattern.
- **Step 2:** ***Reading Brain by EEG*** - when the developed potential pattern is read by EEG (or other similar techniques) to be transformed into an analyzable signal patterns. This is also known as EEG spectrum.
- **Step 3:** ***Analysis of EEG spectrum*** - the signal pattern developed by EEG equipment is analyzed using various pattern analysis techniques.

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BRAIN-COMPUTER INTERFACE

- **Step 4: *Recognizing EEG spectrum*** - based on the signal analysis we recognize what task brain wants to get from computer or mobile device.
- **Step 5: *Converting into suitable computer signal*** - once we know the task to be done we can easily determine proper computer command (or sequence of command) to get the task from computer or mobile device.
- **Step 6: *Sending the signals to computer system*** - after discovering the required command or program, send the same to CPU which then execute the required task.

- **Step 7: *Feedback to the user*** - after CPU accepts the input it carries out the operation and sends the feedback to user in various feedback-forms e.g. video, audio etc.
- As is seen, for realization of human-computer interaction with smart mobile applications it is necessary to provide:
  - ***filtering of register brain signals;***
  - ***pattern analysis techniques for clustering of neurons and pattern recognition*.**

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SIGNAL PROCESSING AND CLUSTERING OF NEURONS

- At any moment the human brain generates wave for a particular thought, but at the same time generates also some waves corresponding to other unnecessary thoughts.
- These *additional waves act as noise* for original waves.
- For handling this problem it is necessary to develop some ***noise filtering mechanism*** that can detect the unrelated spectrum and filter them out from the useful spectrum.

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SIGNAL PROCESSING AND CLUSTERING OF NEURONS

- Another problem that have to be solved is connected with ***clustering of neurons***, where it is necessary to ***divide 80-120 billion brain-neurons into few clusters*** and the big question is – on what basis we should divide the neurons?
- For solving this problem is involved Artificial Intelligence and Artificial neural network.

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EXPERIMENTAL METHODS AND MEASUREMENTS

- The experimental BCI system includes 3D camera Panasonic HDC-Z0000, sender Spectrum DX9 DSMX, Sony GoPRO – GoPro HERO3, Nikon D902D smart TV Samsung UE-65HU8500 + LG60LA620S, ACER K11 Led projector, Linksys EA6900 AC1900 smart router, Pololu Zumo Shield, 8 core/32GB RAM/4TB HDD/3GB VGA computer for video processing that translate EEG signals into computer commands and two Electro-Caps (elastic electrode caps)

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EXPERIMENTAL METHODS AND MEASUREMENTS

- Two Electro-Caps (elastic electrode caps) was used to record each from positions C3, C4, P3, P4, O1, and O2, defined by the most popular 10-20 System of electrode placement at experimental setup.
- This system called 10-20 System is an international standard for EEG electrode placement locations on the human scalp.
- Based on results from pilot recordings, we selected the parietal (P3 and P4) regions as the locations of interest.

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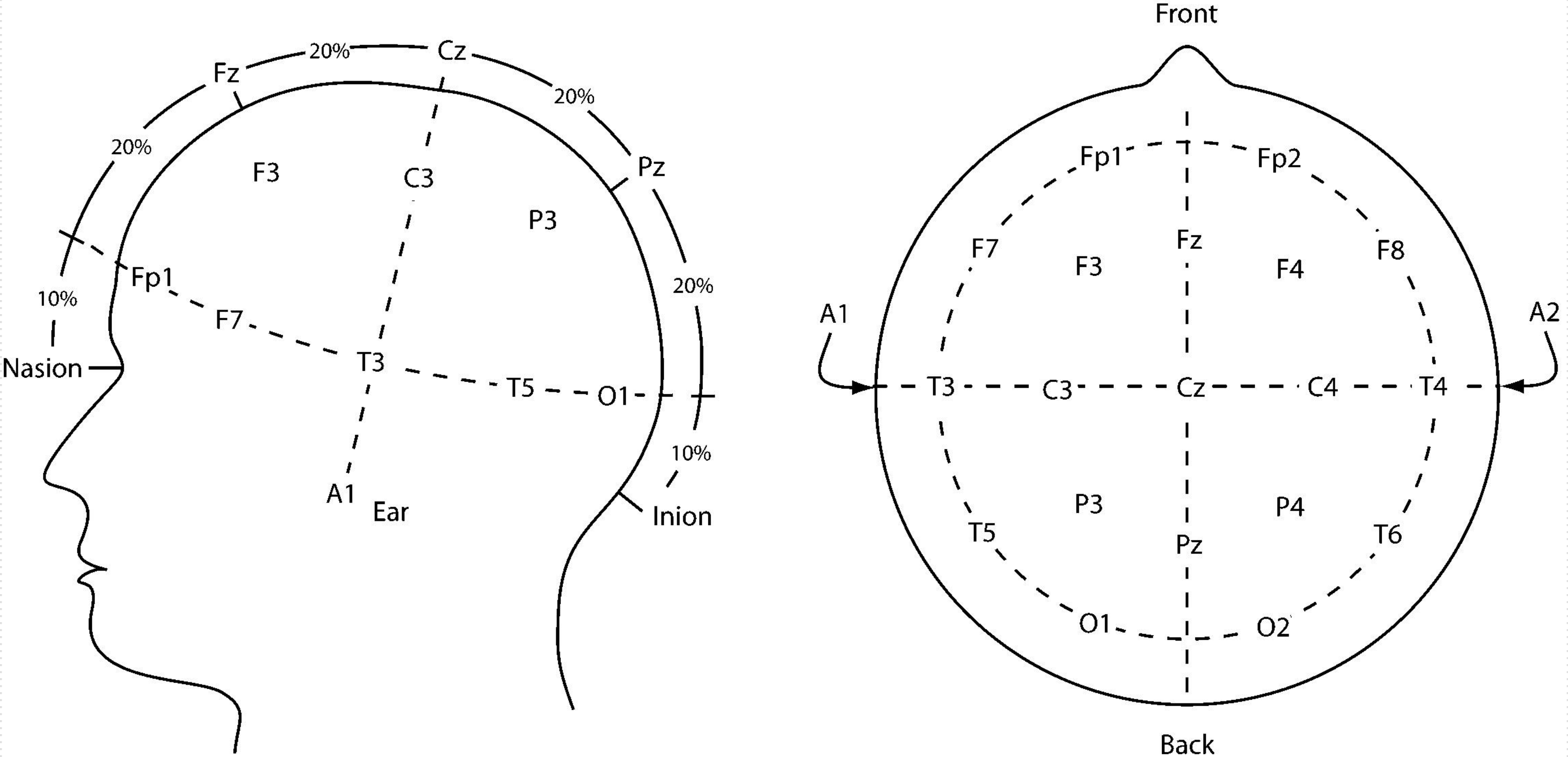
EXPERIMENTAL METHODS AND MEASUREMENTS



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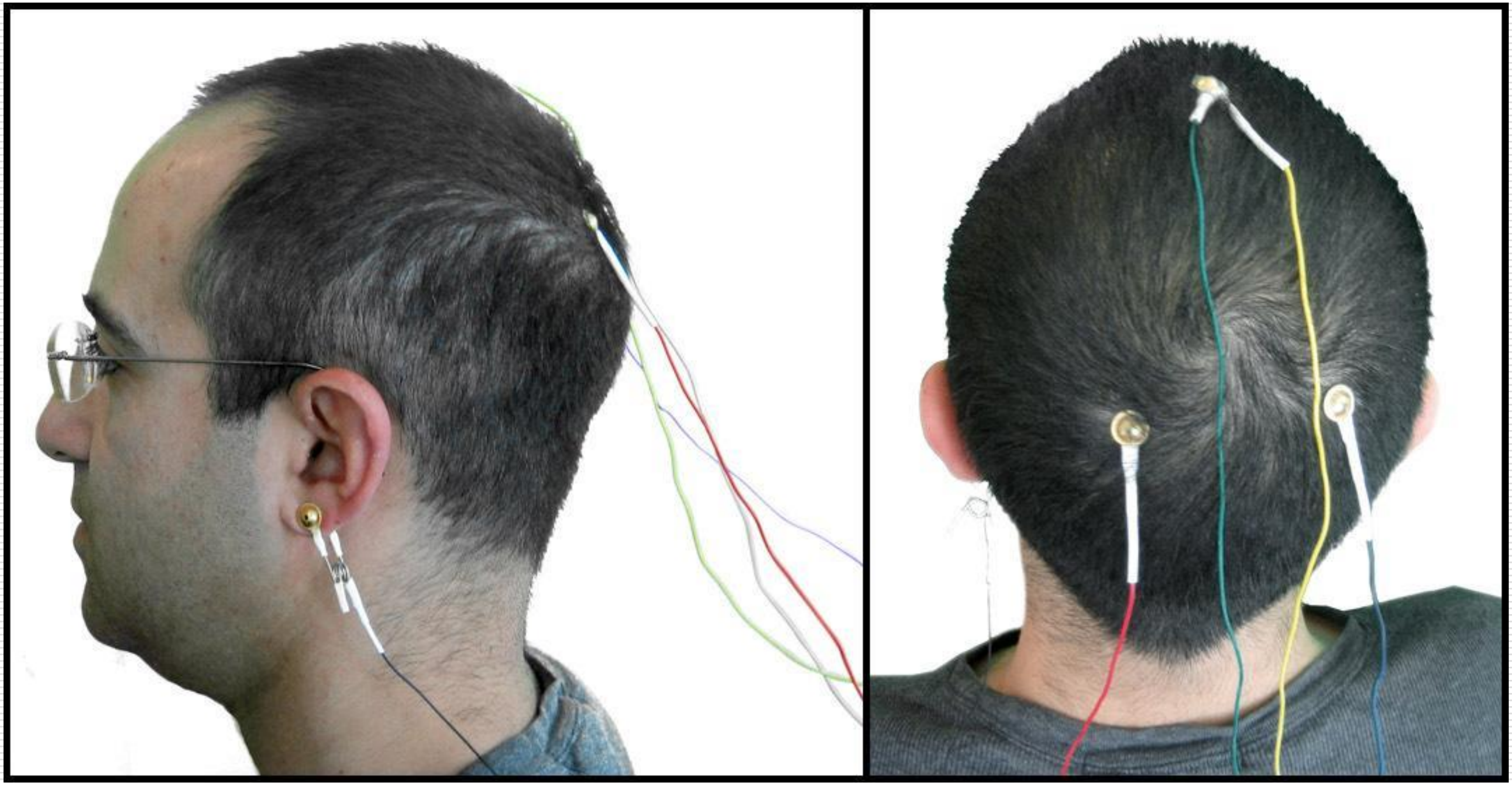
EXPERIMENTAL METHODS AND MEASUREMENTS



EXPERIMENTAL METHODS AND MEASUREMENTS

- The subjects were asked to perform the following ***five mental tasks***:
  - baseline task - for any possible subjects relaxed and not thinking activity;
  - letter - emergency call -subjects dial up 122;
  - math task - imagined addition;
  - counting task - count edges or planes around an axis rotation of 3d graphics;
  - geometric figure rotation - subjects imagine rotation of shown figure.

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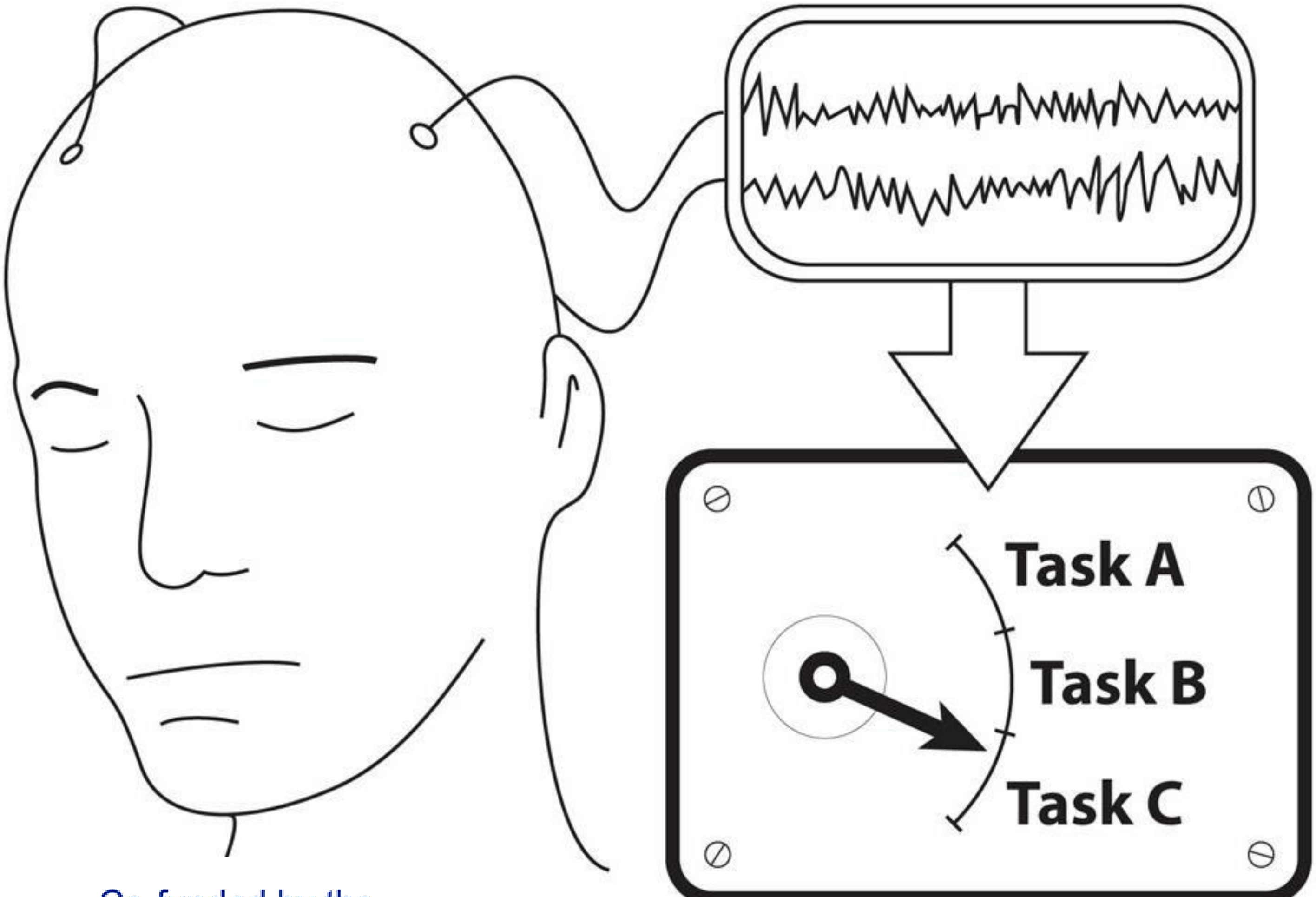
BRAIN-COMPUTER INTERFACE



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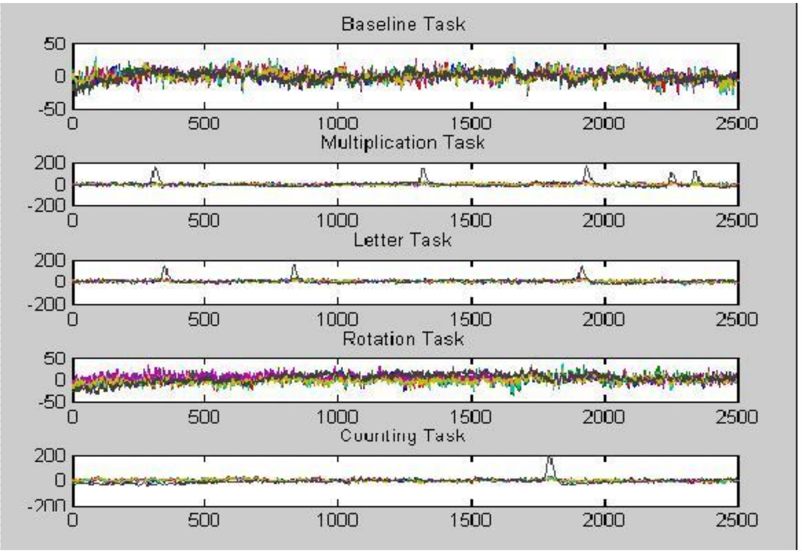
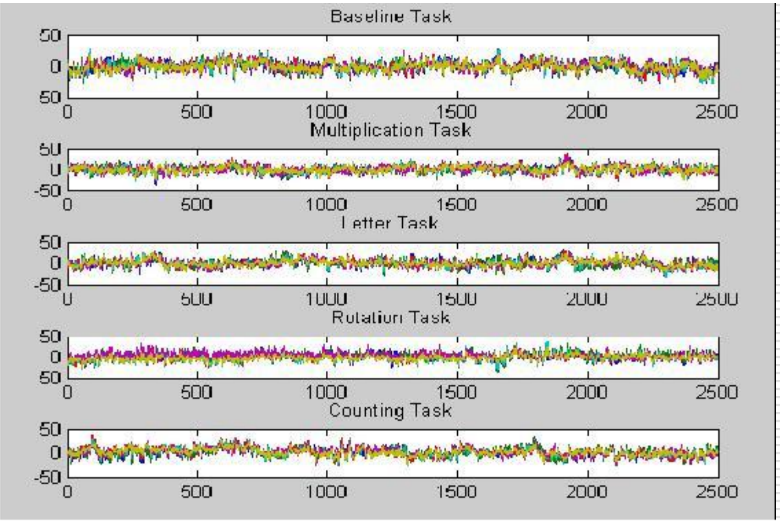
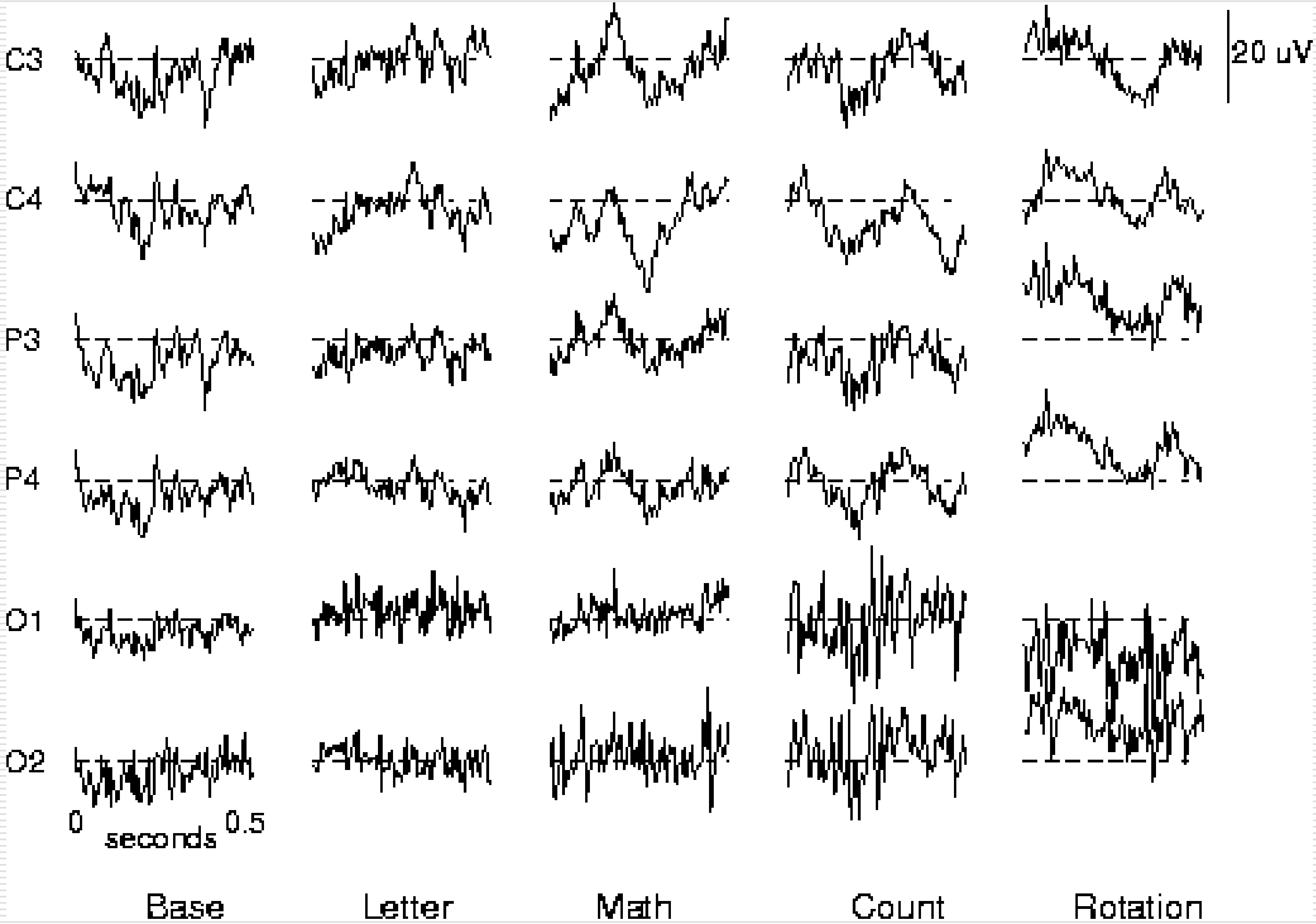
EXPERIMENTAL METHODS AND MEASUREMENTS

- The EEG data are segmented by rectangular windows. The length of each window is 1*s* (200 sampling points). Each mental task is repeated 20 times. Each time lasts 14 seconds. Each channel records 4000 sample data for each test.





EXPERIMENTAL METHODS AND MEASUREMENTS



EXPERIMENTAL METHODS AND MEASUREMENTS

- ***basic signal processing*** to transform the received time series data into a time independent data set;
- ***feature selection*** was processed to prune the feature set, keeping only those that added the most useful information to the classifier and to prevent overfitting;
- Selected features were used to ***train a Bayesian Network and perform the classification***.

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EXPERIMENTAL METHODS AND MEASUREMENTS

- ***spectral power of the signal*** in a set of six standard frequency bands: 4*Hz* (delta), 4-8*Hz* (theta), 8-12*Hz* (alpha), 12-20*Hz* (beta-low), 20-30*Hz* (beta-high), and 30-50*Hz* (gamma).
- In this work was used 18-fold cross validation, instead of standard 10-fold cross validation, to control the block design of the data collection procedure. For each fold, the model trained on 9 of the 10 available trials and reserved one trial for testing. A trial contains 13 contiguous windows for each task.

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EXPERIMENTAL METHODS AND MEASUREMENTS

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EXPERIMENTAL METHODS AND MEASUREMENTS

- Each of reported results is the mean classification accuracy after repeating this process 10 times using a different test trial for each fold.

Subject number	**Mental Tasks**				
	Base	***Letter***	***Math***	***Count***	***Rotate***
1	91.3%	63.4%	75.7%	69.4%	74.5%
2	92.4%	72.5%	78.3%	79.9%	67.2%
3	87.8%	78.8%	64.2%	78.6%	80.1%
4	90.2%	69.6%	69.7%	69.4%	78.2%
5	93.7%	67.5%	78.9%	76.4%	63.4%
6	89.3%	62.7%	80.2%	73.8%	78.1%
Mean	90.8%	69.08%	74.5%	74.58%	73.6%

- classification accuracies with Bayesian Network classifiers for five mental tasks

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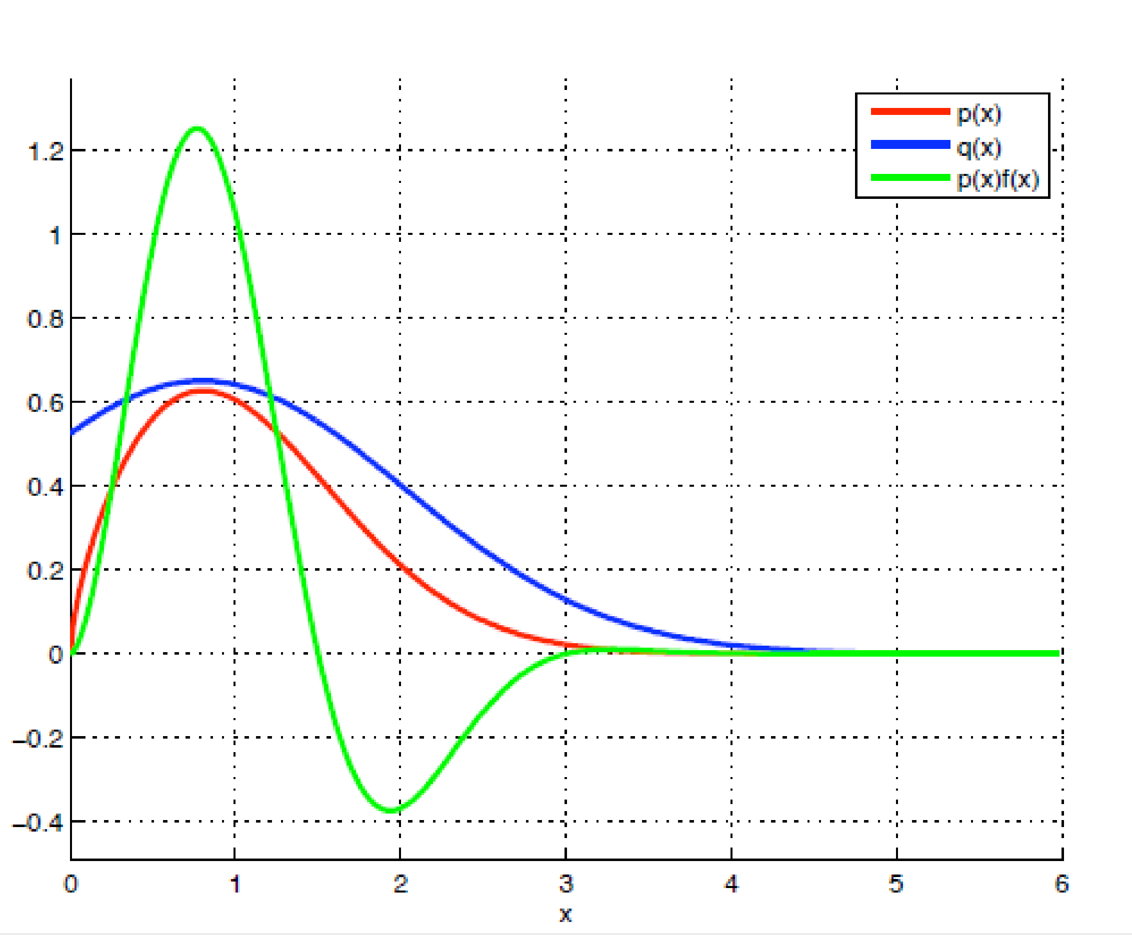
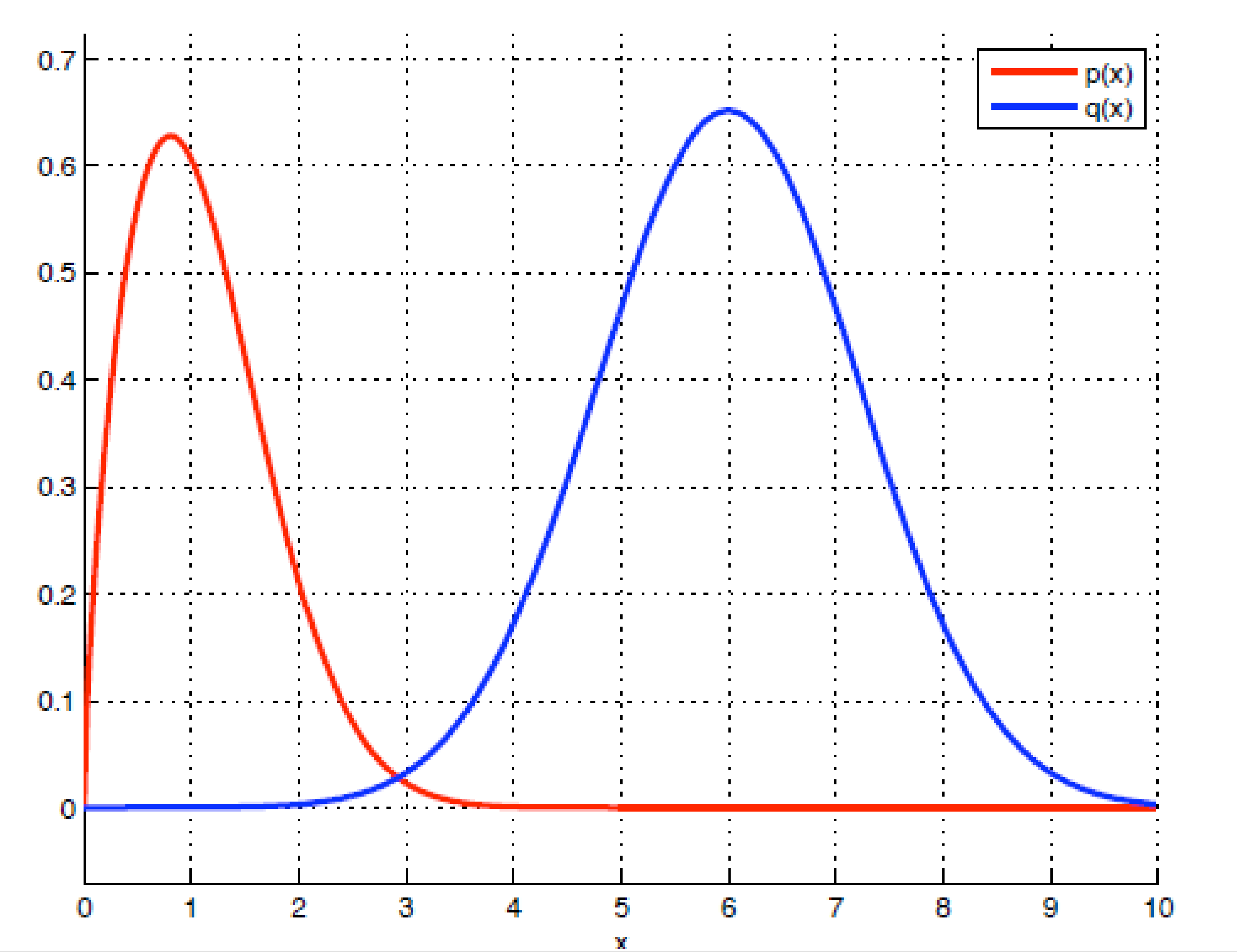
EXPERIMENTAL METHODS AND MEASUREMENTS

- Comparison between received results with Bayesian Network classifiers and pair-wise classifier



- shifting the mean of the sampling distribution



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Conclusions

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- An approach for HCI with classification of recorded electrophysiological signals at different mental tasks for connection via BCI with smart mobile applications is suggested;
- With considered experimental setup of brain-computer interface were provided experiments with six subjects for execution of five mental tasks.
- The measured outputs after noise filtering were classified with Bayesian Network classifier and with of pair-wise classifier.

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