Biomedical Engineering Innovation in Healthcare: from Innovation to Commercial Product
Case Study in Brain Computer Interface (BCI) Innovation

Yodchanan Wongsawat, Ph.D.

BCI Lab Director
Department of Biomedical Engineering
Faculty of Engineering, Mahidol University, THAILAND
Idea
Passion
Royalty
I fix
Human
STROKE

อัมพาต
RIGHT side damaged

LEFT side affected
Over a billion people!
(15% of the world’s population)
live with disability

“190 million” have severe disability

Ref: WHO: World report on disability 2011 (www.who.int)
Paraplegia
Let’s learn how to fix them
Largely “accessible”.
Single cells of the nervous system

Pyramidal cell

100,000,000,000 in your brain

Source: Hubel
EEG Electrode

EEG Amplifier

Scalp

Skull

Dura Mater

Arachnoid

Subarachnoid Space

Pia Matter

Active Synapses

Pyramid cells

Efferent Axon
Beta (β) 13–30 Hz

Theta (θ) 4–8 Hz

Delta (δ) 0.5–4 Hz
Trends on BCI

Brain Computer Interface (BCI)

- Preventive Tech.
- Treatment
- Signal Processing
- Robotics
- Rehabilitation & Assistive Tech.

Medicine
Highlight Projects

BCI for Rehabilitation and Assistive Technology
• EEG-based Wheelchair Control
• Neuroprosthetic Communication Device (iThink2)
• BCI-based Robotic Arm
• BCI-based Rehabilitation Devices

BCI for Treatment
• Neurofeedback Device for Attention Enhancement
• Peripheral Nerve Localization by Frequency-Based Electrical Stimulation

BCI for Preventive Technology
• Real-time Sleep Analysis System
• BCI in Golf/Soccer

Ongoing Project
P300 Brain-Controlled Wheelchair

Signal Processing task

- EEG Signals recording
- P300 stimulation
- 3 times of Eyes-blinking
- User sit on brain-controlled wheelchair

Output command

Navigation task

- Manual Control Mode
  - Forward, backward, turn left, turn right
- Automatics Navigation Mode
  - 4 times of Eyes-blinking
  - Obstacle appear

Stop command by 2 times of Eyes-blinking

Stop command indicator
Start stimulator indicator
Mode changing indicator
SSVEP-based BCI for Smart Home

Using Brain Signal (EEG) to wirelessly control electrical devices by looking at the visual stimulation patterns

Recent Status: Clinical Trials with Spinal Cord Injury (SCI) Subject and Plan to Commercialize in Year 2012

Supported by TRIDIR

Recent Status: International Patent Pending
Technology puts mind over body

Disabled people can communicate and operate electronic devices just with the power of thought, writes Suchit Leesa-nguansuk

A patient demonstrates how the Brain Computer Interface (BCI) technology can help quadriplegics control wheelchairs by triggering commands triggered by thought.

Bangkok Post

Bangkok Post : 24 November 2010
iThink2  (Funded by NTC)

Turn On
- TV
- LAMP
- RADIO
- FAN

Turn OFF
- RADIO
- FAN
- TV
- LAMP
Clinical Trials
Steady-State Auditory Evoked Potentials (SSAEP)
SMS/Phone Call using BCI
Assistive Technology

iCREATe 2012,
BCI based Assistive Robot Arm

ERD/ERS  Hybrid EOG-EEG
• Electrode Placement
  – Deltoid
  – Biceps brachii
  – Flexor digitorum
  – Extensor digitorum
BCI-FES

- Average of Grabbing Force (8 subjects)

![Graph showing force over time with different voltages]

Start Stimulation

Force Sensor
BCI–based Rehabilitation Device

Video (23:00)
Highlight Projects

**BCI for Rehabilitation and Assistive Technology**
- EEG–based Wheelchair Control
- Neuroprosthetic Communication Device (iThink2)
- BCI–based Robotic Arm
- BCI–based Rehabilitation Devices

**BCI for Treatment**
- Neurofeedback Device for Attention Enhancement
- Peripheral Nerve Localization by Frequency–Based Electrical Stimulation

**BCI for Preventive Technology**
- Real–time Sleep Analysis System
- BCI in Golf
EEG–Biofeedback (for ADHD)
(Funded by Mahidol University)
19-channel EEG Analysis
Meditation Project

- Study the efficiency of current Buddhist meditation to the brain
- Invent the new binaural beat-based meditation for some specific purpose, e.g. reduce bruxism during sleep

![Binaural beat diagram](image_url)
Some pictures during the experiment
Active Play Project
Introduction

Vestibular schwannoma / Acoustic neuroma / Cerebellopontine angle tumor

http://www.acoustic-neuroma-brain-tumour.org/english

It is very difficult to remove this tumor. 7th and 8th cranial nerves are risky damaged during tumors resection.
Introduction

Conventional Nerve localization

Surgical manipulation

Problems

Surgeon sometime miss to localize the nerve because nerve discharge could be induced even when surgical manipulator does not irritate to the nerve.
Materials and Methods

Postoperative Nerve Function Assessment

The proposed method of nerve function estimation

Nerve model

\[ h_\theta(x) = \theta_0 + \theta_1 x = y \]
\[ \theta = (X^T X)^{-1} X^T y \]

Stimulus intensity (Input (x))

- Incision - manipulation

Level 1

Level 2

Level 3

Level 1

Level 2

Level 3

tEMG (output (y))
What is TENS?

Transcutaneous Electrical Nerve Stimulation

Stimulate TENS with high Frequency

Pain Controlled System
Timing detail
On push button
5 second
25 second
25 second

Timing detail
On push button
5 second
25 second…

6 cycles
First, the condition of baseline paradigm is designed for get the result of the brain activity when subject look at a plane/blank presentation. The result come from the first baseline paradigm is shown in Fig. 4.4.1. As the result there is a red color appear in an area of Anterior Cingulate Cortex (ACC). An Anterior Cingulate Cortex is function of an emotional aspect of pain.

Fig. 4.4.1 fMRI image in transverse plane|

Second, the condition of task paradigm is designed for get the result of the brain activity when subject look at the distract presentations. The result come from the second task paradigm is shown in Fig. 4.4.2.

Fig. 4.4.2 fMRI image in transverse plane
Highlight Projects

BCI for Rehabilitation and Assistive Technology
- EEG-based Wheelchair Control
- Neuroprosthetic Communication Device (iThink2)
- BCI-based Robotic Arm
- BCI-based Rehabilitation Devices

BCI for Treatment
- Neurofeedback Device for Attention Enhancement
- Peripheral Nerve Localization by Frequency-Based Electrical Stimulation

BCI for Preventive Technology
- Real-time Sleep Analysis System
- BCI in Golf
EEG-BASED BEHAVIORAL ENHANCEMENT SYSTEM

Asst.Prof.Dr. Yodchanan Wongsawat
Lect. Jetsada Arnin
Brain-Computer Interface Laboratory (BCI LAB)
Department of Biomedical Engineering
Faculty of Engineering, Mahidol University

BCI LAB
Exploring Your Mind.

Toward the future, cutting edge technology of brain-computer interface (BCI) will be commercially employed for accidental vigilance, rehabilitation and smart medical treatment.
Logistic Markets

ASEAN $4 billion

Thailand $0.4 billion

Indonesia $2.8 billion
Accidents from Drowsiness

Thailand:
- $700 million damage per year
Drowsiness Facts

- 30% Drowsiness Accidents
- 75% Drowsy Driving
IEL: Cost of Accidents

- 2008: $2.2 million
- 2009: $2.4 million
- 2010: $2.6 million
- 2011: $2.8 million
- 2012: $3.0 million

- 2008: $1.6 million
- 2009: $1.7 million
- 2010: $1.9 million
- 2011: $2.0 million
- 2012: $2.2 million

Cost from total accidents
Cost from drowsiness accidents

= drivers killed
BCI–based Sleep Research

**Awake:** low voltage – random, fast

**Drowsy:** 8 to 12 cps – alpha waves

**Stage 1:** 3 to 7 cps – theta waves

**Stage 2:** 12 to 14 cps – sleep spindles and K complexes

**Delta sleep:** (stages 3 and 4) ½ to 2 cps – delta waves >75 μV

**REM sleep:** low voltage – random, fast with sawtooth waves

Sigma waves

K complex
EEG Sleep Stages

SEQUENCES OF STATES AND STAGES OF SLEEP ON A TYPICAL NIGHT

Stages

Awake

Hours of Sleep

0 1 2 3 4 5 6 7 8
Investigating the best time for power napping

Sleeping competition was nothing to yawn at

The benefit of having a quick afternoon nap is being looked at scientifically

Published: THA/2024 12:30 AM

As an engineer, 37-year-old Sompong Sansavan says he has sufficient sleep each night because he is often out of direct working at a car manufacturing plant in Japan.

However, during driving conditions must be constant in 'hypnagogia phase', the foundation's president, K. Tanaka, said. "This factor is much devalued and not well understood."

Driving is divided into four stages. Stage one refers to the transition after sleep or wake in the awake state of 0.5-3 Hz in a 4-5 hour drive to driver fatigue. Some people having sleepiness in this state may lose some muscle tension and awareness of their external environment, resulting in road accidents.

Stage two, which is the focus of the competition, represents the period when people could sleep well and would be more prominent when working.

The competition, conducted for those who were partners for the first two years, would not interrupt points from the organization.

Mr. Sompong was one of the car enthusiasts who would enter the second level of sleeping with 25 minutes.

On less than full sleep, drivers should return to a nap after reaching the second level of sleeping before falling on the road again. This could help reduce road accidents caused by drowsy driving.

In the United States, drowsiness is believed to be responsible for one of death due to road accidents. The study shows how different stages of sleep and awareness which can generally be detected in the polysomnography machine available at large-scale hospitals for treating patients with sleep issues.

This world polysomnography machine is specifically designed to measure if a motortaxi driver is taking a nap between long drives.
Experimental Design

• Waking up 3 minutes after stage 2 sleep
  – 21 subjects (both male and female excluding 5 subjects from first experiment)
  – 5 levels of questionnaire (level 1 = Sleepy, level 5 = Fresh)
The Drowsiness
Product Trials
ALERTZ

“Anti-Drowsy Driving Alarm”
Alertz Specification

- 72 Hours Operating
- 7 Days data loggers
- EEG/EOG Signal Detector
- Bluetooth v4.0 LE Interface
- Water Proof IP65
- Rechargeable Battery
- ROHS complaint
- Alarm with Vibration
Alertz : Software

Feature

- Display Reports
- Administrator Management (Permissions)
- Limit User Accounting
- User/Product ID Management
- Database Management
- Easy to Installation and Upgrade
- Connect to Product via Bluetooth 4.0
- Operating System with Windows (64 bit only)
Alertz : Software

Station Manager

Mr. John Doe
ID : DRIVER-002
Last Trip: 14 Feb 2015 20:19
10 Alarms In 4 Hours 16 Minutes

<table>
<thead>
<tr>
<th>ID</th>
<th>Name</th>
<th>Last Trip</th>
</tr>
</thead>
<tbody>
<tr>
<td>DRIVER-001</td>
<td>Mr. Brian Doe</td>
<td>14 Feb 2015  8.35</td>
</tr>
<tr>
<td>DRIVER-002</td>
<td>Mr. John Doe</td>
<td>14 Feb 2015  20.19</td>
</tr>
<tr>
<td>DRIVER-003</td>
<td>Mr. Tom Doe</td>
<td>13 Feb 2015  19.52</td>
</tr>
</tbody>
</table>
Alertz : Software
Alertz : Software
**Business > News**

**Good Vibrations**

A new device analyses brain waves to warn drivers before they nod off

Published: 12 Apr 2013 at 00:00  
Newspaper section: Business

As Songkran arrives, Thais are again warned to steer away from drunk driving during the water-splashing festival to prevent what is usually a spike in road accidents.

Researchers at Mahidol University’s department of biomedical engineering have devised a patent-pending sleep alarm system to detect drowsiness via brain signals.
Contribution & Conclusion

- Portable wireless brainwave monitoring system and innovative dry-electrode headband

- Automatically detect drowsiness in **real time** and alarm in case of drowsiness occurrence
Sleep Lab System

Main System Box

Hub System Box

Abdomen gauge

Cannula

Thorax gauge

Thermistor

SpO2

Sensor part

Signal processing part
### Sleep LAB Monitoring

**Patient name:** Test

<table>
<thead>
<tr>
<th>Channel</th>
<th>Waveform</th>
</tr>
</thead>
<tbody>
<tr>
<td>C3</td>
<td></td>
</tr>
<tr>
<td>C4</td>
<td></td>
</tr>
<tr>
<td>O1</td>
<td></td>
</tr>
<tr>
<td>O2</td>
<td></td>
</tr>
<tr>
<td>REOG</td>
<td></td>
</tr>
<tr>
<td>LEOG</td>
<td></td>
</tr>
<tr>
<td>EMG</td>
<td></td>
</tr>
<tr>
<td>ECG</td>
<td></td>
</tr>
<tr>
<td>Nasal</td>
<td></td>
</tr>
<tr>
<td>Therm</td>
<td></td>
</tr>
<tr>
<td>Thor</td>
<td></td>
</tr>
<tr>
<td>Abdo</td>
<td></td>
</tr>
<tr>
<td>SpO2</td>
<td></td>
</tr>
<tr>
<td>HR</td>
<td></td>
</tr>
</tbody>
</table>

**Epochs:** 30 sec | Pause | STOP
BCI for Sport Analysis

Real-Time Prediction of Successful Golf Putting via multichannel EEG
Highlight Projects

BCI for Rehabilitation and Assistive Technology

- EEG-based Wheelchair Control
- Neuroprosthetic Communication Device (iThink2)
- BCI-based Robotic Arm
- BCI-based Rehabilitation Devices

BCI for Treatment

- Neurofeedback Device for Attention Enhancement
- Peripheral Nerve Localization by Frequency-Based Electrical Stimulation

BCI for Preventive Technology

- Real-time Sleep Analysis System
- BCI in Golf/Soccer
Idea
Passion
Royalty