

뇌-기계접속 연구의 동향



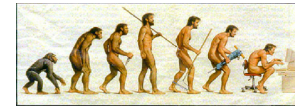
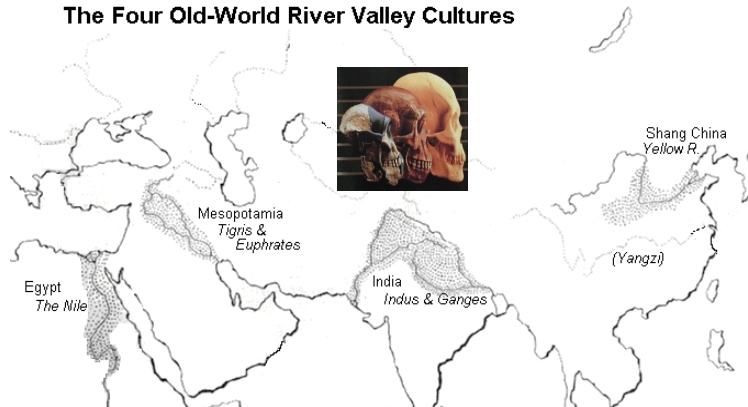
Verbal Expression

Yes! No!	How are you? Are you OK?	Is this? Do you want? Can I do for you? Is wrong? Is so good?
	Do you Let's What	wants to play game. want to sing a song Love you!
Love me? Want songs? Want to play? Want to turn the light on? Want a game?	Go out. play! talk! eat. Go home.	Am hungry. Feel good! Feel sad! Am lonely. Feel sick.

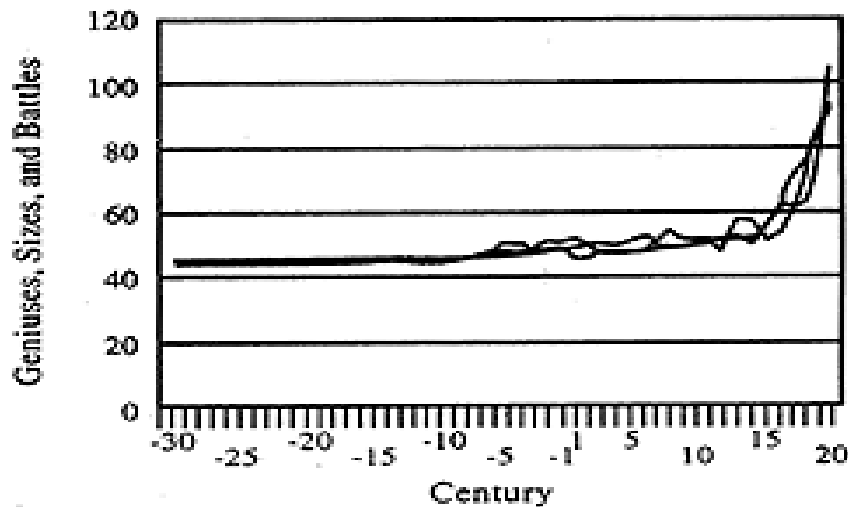
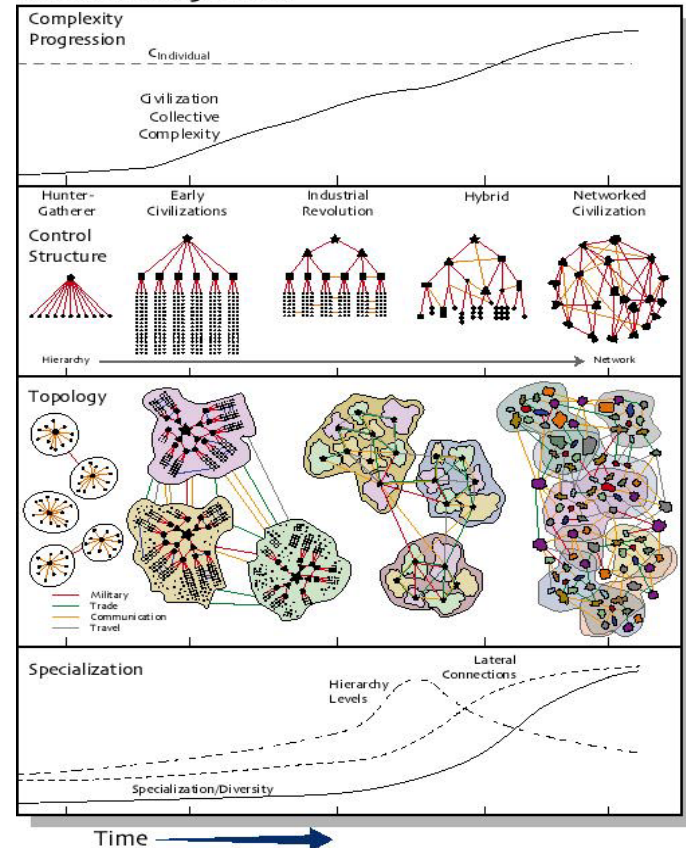
Command Expression
Sound indow



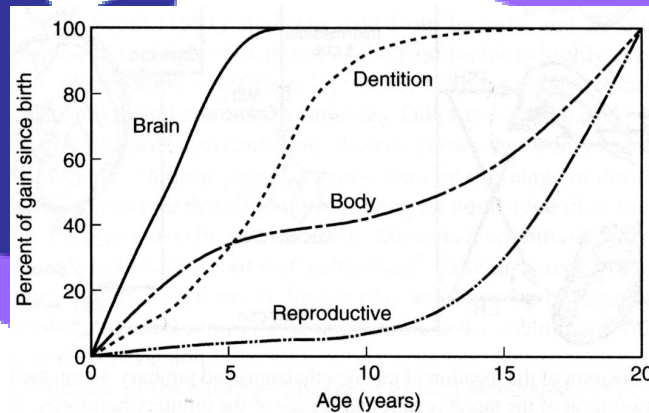
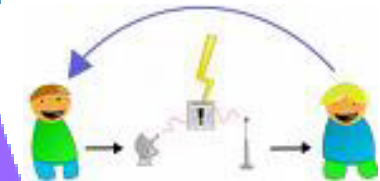
The Four Old-World River Valley Cultures

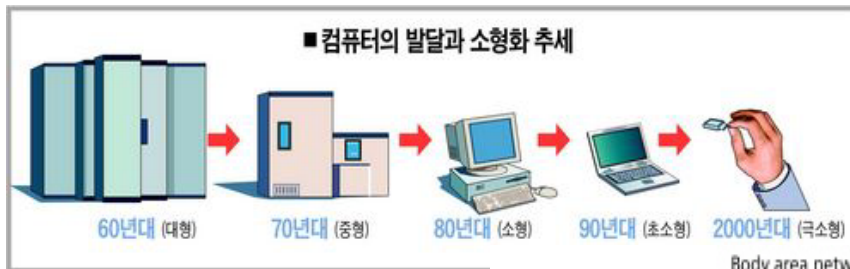


Historical Progression



Civilizations, empires and wars





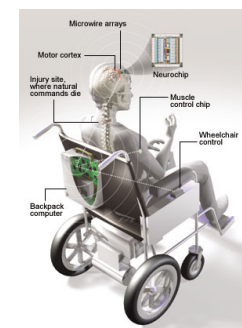
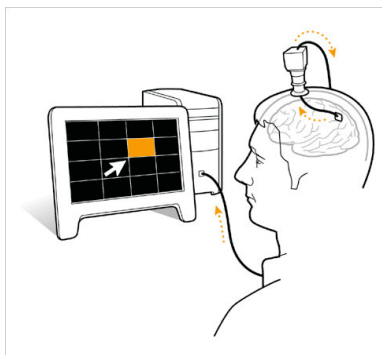
- 배낭 컴퓨터
무선 통신이 가능한 컴퓨터. 6월 공개
되는 HAL-4에서는 허리에 장착하는
소형 컴퓨터로 바뀜
- 배터리
로봇다리를 움직이는 전기모터
- 각도 센서
영양이, 무릎, 발목 관절의 각도 변화 감지
- 생체전기 센서
뇌가 근육에 운동신호를 보내면
피부 표면에 미세한 전류 발생.
이를 감지해 모터를 움직이게 해서
로봇다리가 사람의 다리를 대신함

(사진제공 일 스쿠비대)





인간(뇌) + 기계(컴퓨터)





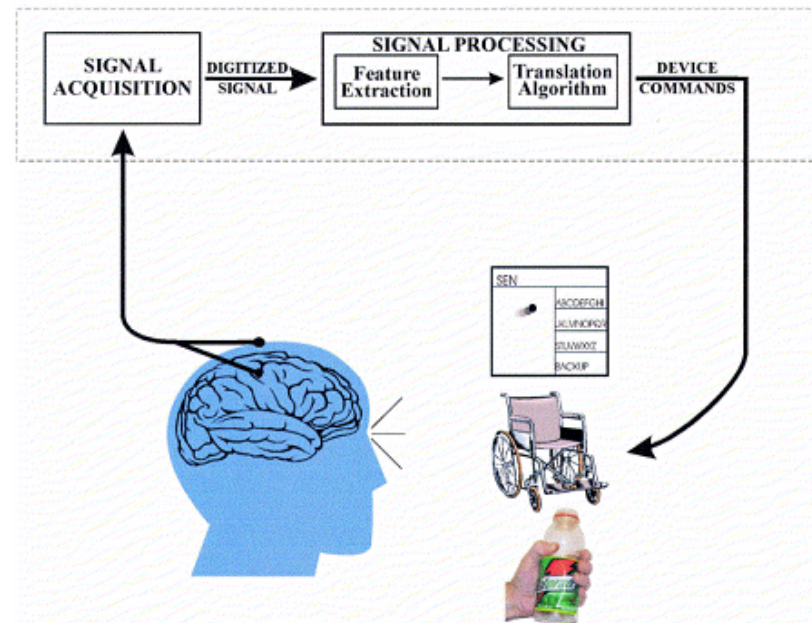
Super

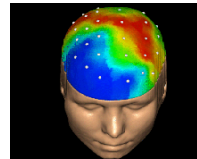
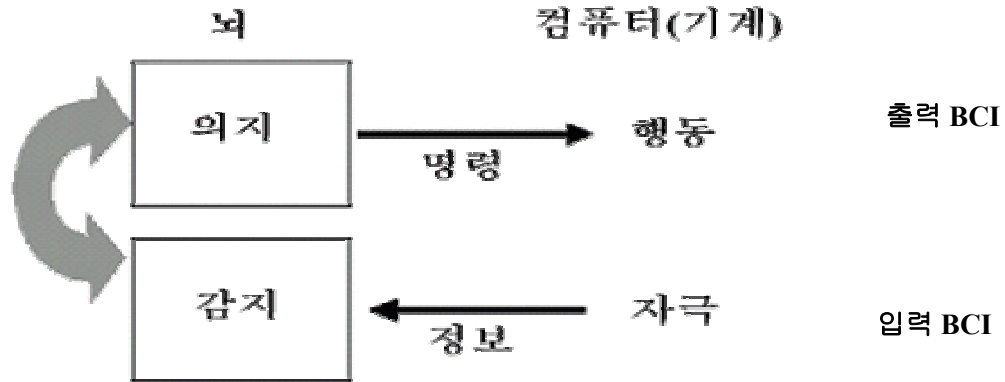


Normal

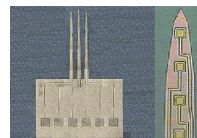
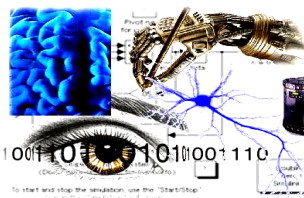


Abnormal





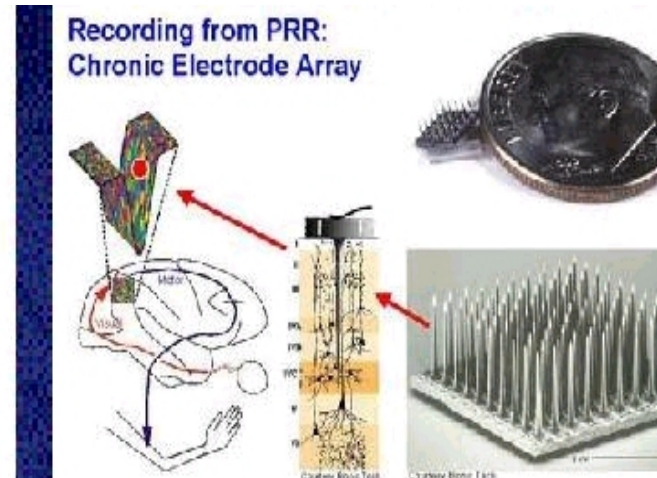
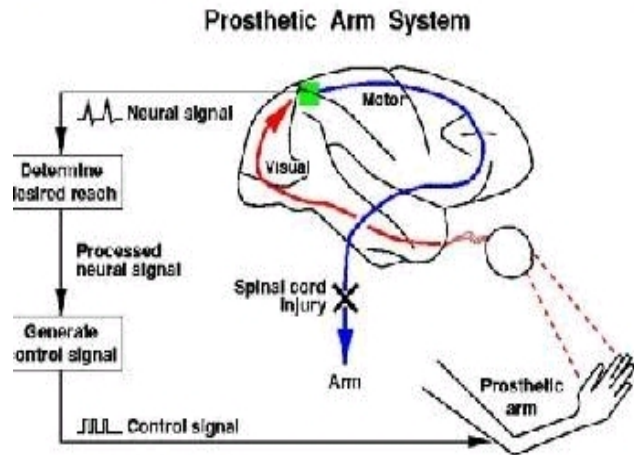
간접 BCI



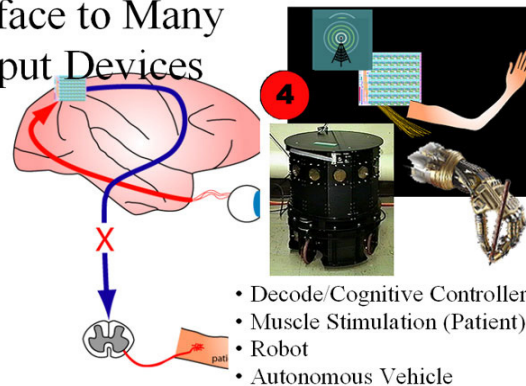
직접 BCI

Donoghue JP. Connecting cortex to machines: recent advances in brain interfaces. **Nature Neurosci.** V.5 1085-1088 (2002)

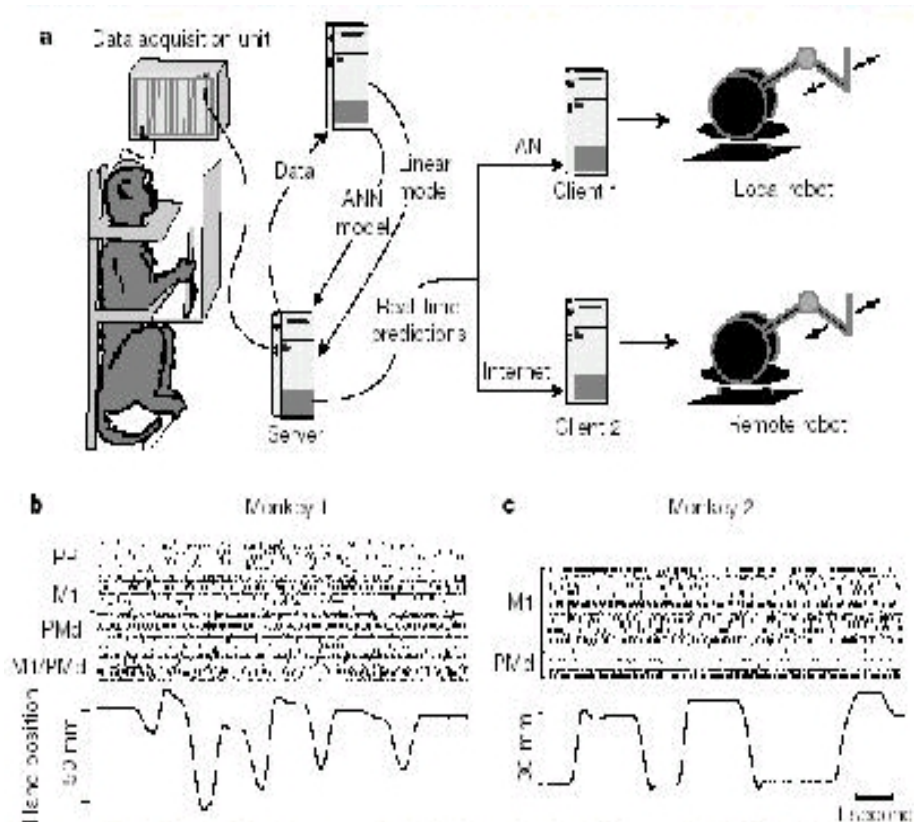




Interface to Many Output Devices



BCI with Neurons in Motor Brain Area



Duke University Medical Center neurobiologist Miguel Nicolelis with an owl monkey and a robot arm which monkeys learned to operate using only their brain signals

CNN.com

현재 태동기, 앞으로 세상을 바꿀 나날 주요 신기술, 앞으로 대규모의 산업시장을 형성할 것으로 예측됨.

세계적으로 권위 있는 여러 기관에서 뇌-기계 접속기술을 21세기 유망 신기술로 선정하였으며, 앞으로 거대시장을 형성할 것으로 예측함.

The New York Times



BUSINESS 2.0



- 1) '05년 8월, 국가과학기술위원회→
21개 미래 국가 유망기술 중 10번째
(Humanoid 로봇 및 뇌-기계접속)
- 2) '02년 미국 NSF, 상무성 보고서→
인간능력향상을 위한 핵심적 융합기술,
'02년 NY Times→21세기 8대
신기술 선정.
- 3) '01년 MIT Technology Review--
→21세기 10대 신기술 중 하나로 선정,
Business 2.0→세상을 바꿀 8
대 신기술로 선정.



장애인



정상인?

기술명	예측 실현 시기	내용
1. 핵융합기술	2026	핵이 융합되는 과정에서 생기는 막대한 에너지 이용 기술
2. 유비쿼터스 사회기반구 축·관리기술	2013	사회기반시설의 정보를 국가차원에서 통합적 운용·관리기술
3. 해양영토관리와 이용기술	2017	해양 영토의 효율적 관리·이용을 위한 디지털 해양환경 관리 이용시스템 기술
4. 초고성능 컴퓨팅기술	2012	유비쿼터스 컴퓨터, 착용형 컴퓨터 등 언제 어디서나 접근 가능한 네트워크 기술
5. 인공위성기술	2017	인공위성을 통해 기상·해양을 상시 관측, 고품질 통신서비스 등을 제공하는 기술
6. 고부가 생물자원기술	2015	생물자원을 이용해 기능성 신소재를 발굴하거나 의약품을 개발하는 기술
7. 재생 의·과학기술	2017	줄기세포를 이용해 다양한 세포나 조직 생산·활용하는 기술
8. 나노·고기능성 소재기술	2015	나노소자가 집적된 나노시스템 생산, 기능성 나노소재, 친환경소재 개발 기술
9. 기후변화 예측·대응기술	2015	장단기 생태환경 변화와 그로 인한 환경재해 등에 대처하는 기술
10. 인지과학·로봇기술	2017	휴머노이드 로봇, 뇌와 기계의 인터페이스, 생체정보 감지·처리 기술

뇌-컴퓨터 접속 슈퍼 쥐



+



=>

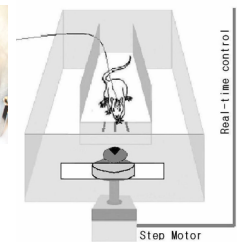
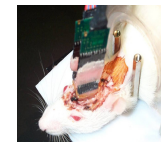
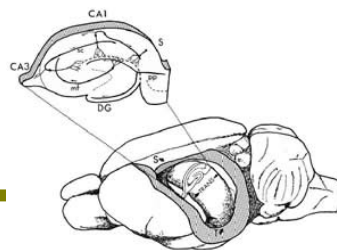
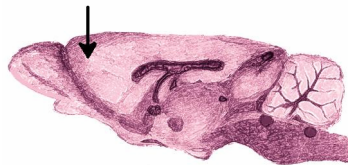
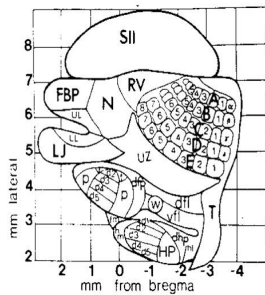
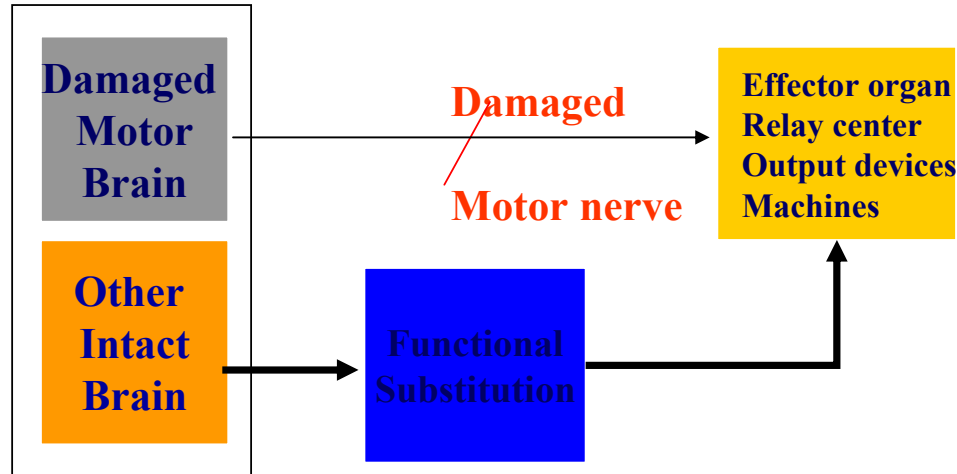


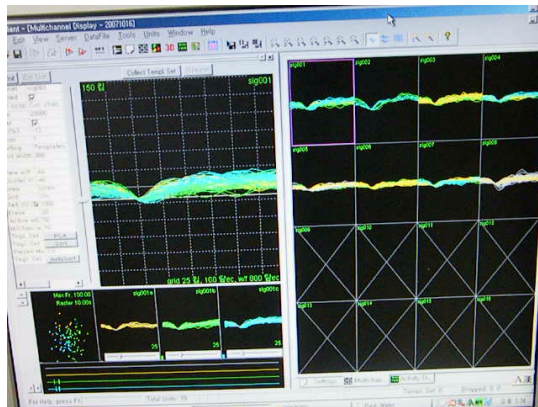
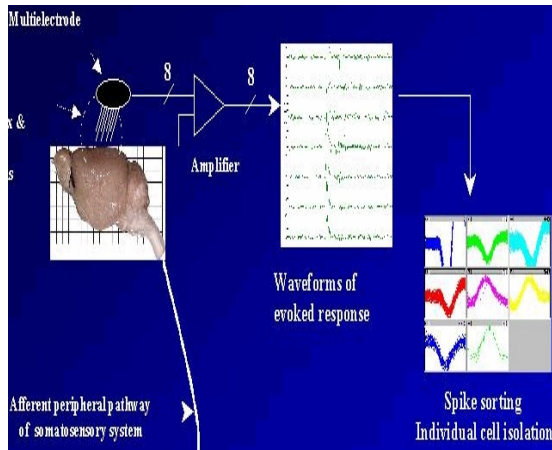
+

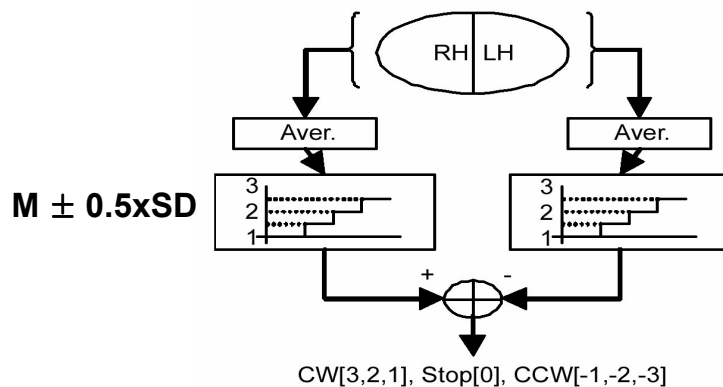
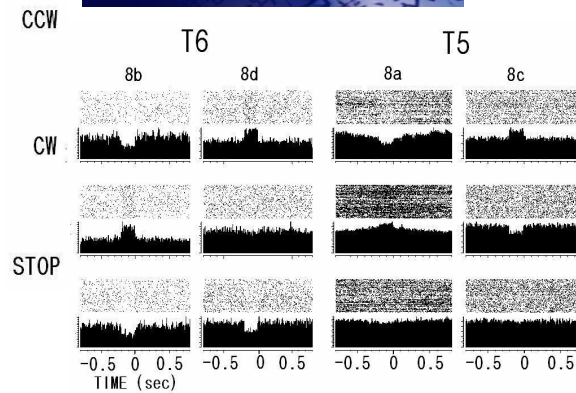
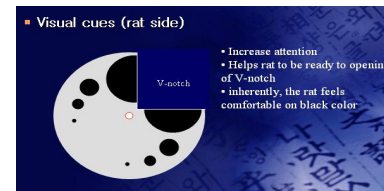
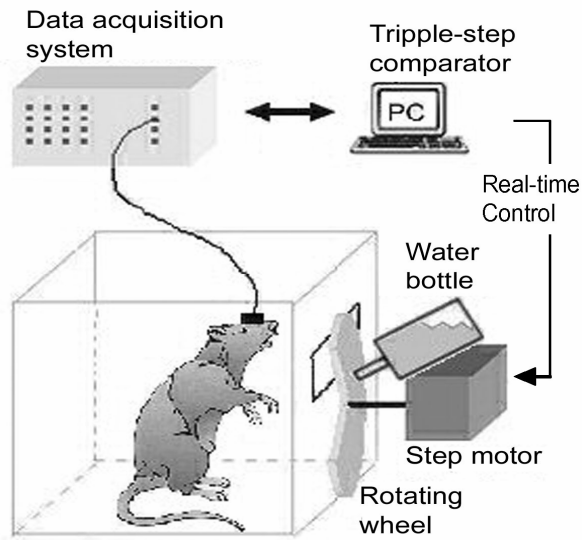


If,
When

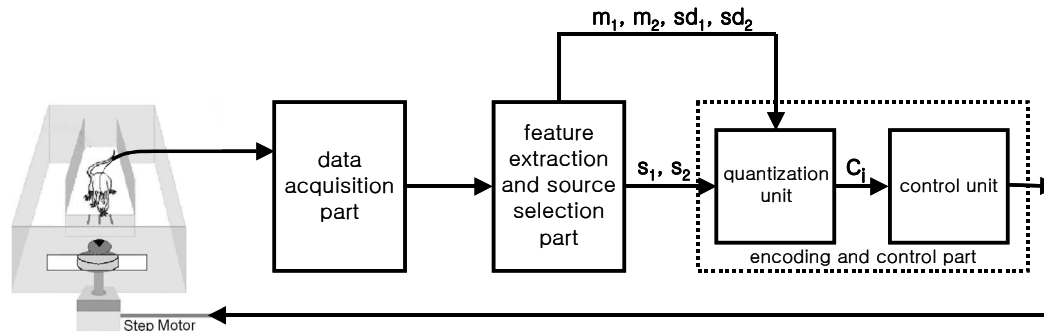
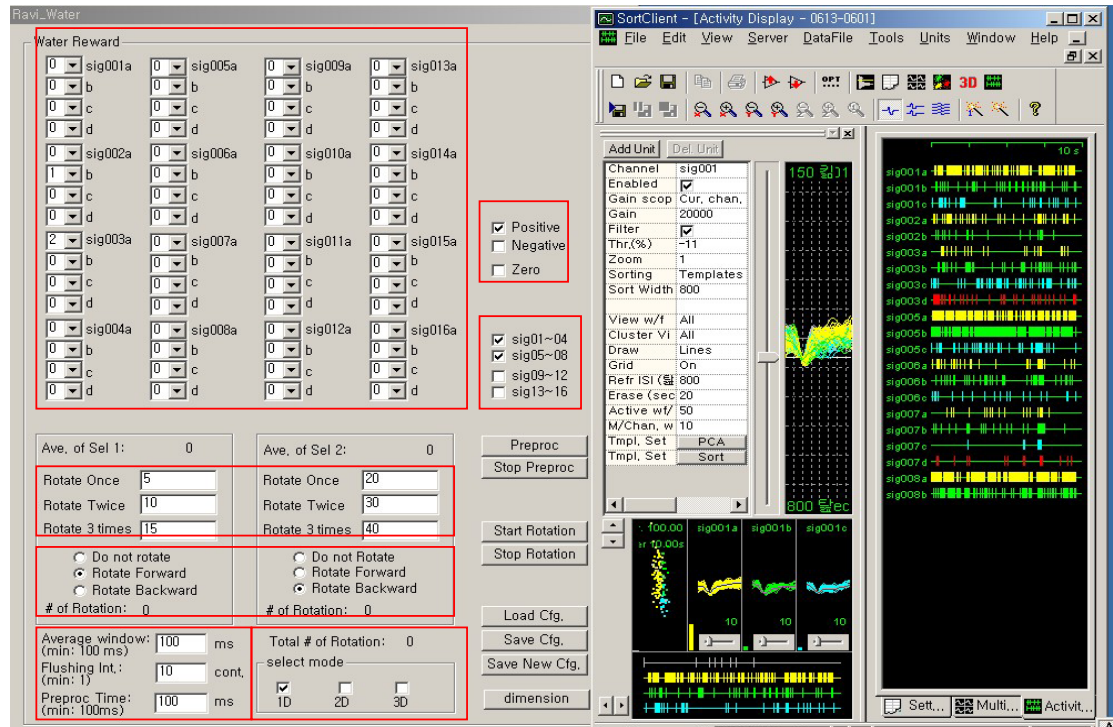
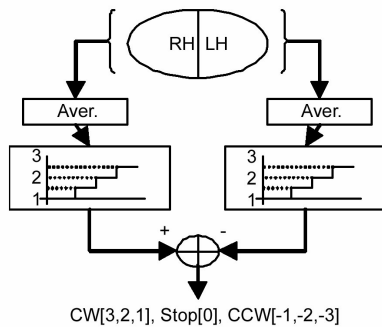
then

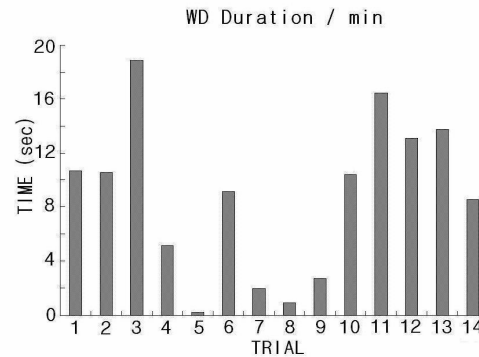
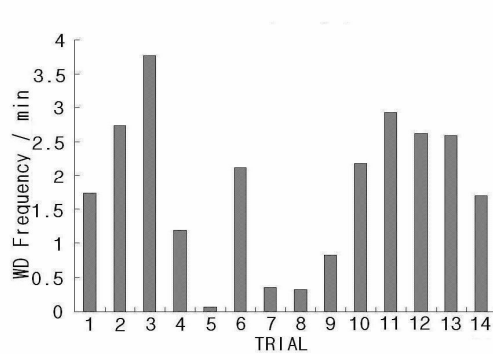




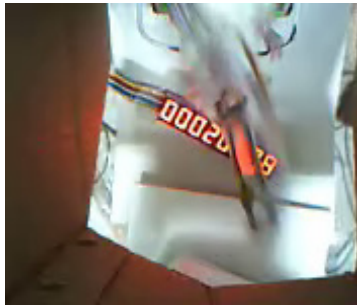


Patent No.10-2005-0037579
 NEURAL SIGNAL BASED CONTROL DEVICE AND
 CONTROL METHOD BASED NEURAL SIGNAL

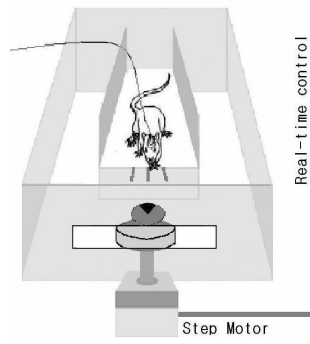




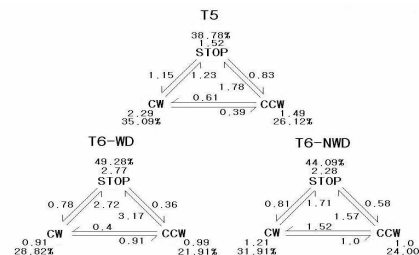
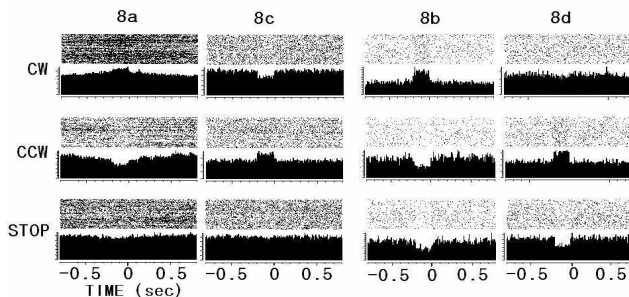
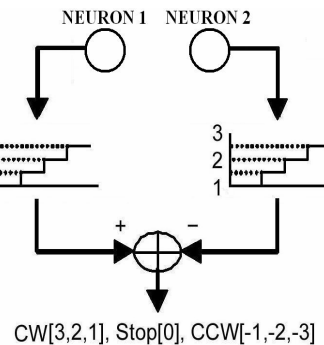
TRIAL No.	GROUP 1	GROUP 2
1	RH16	LH18
2	LH11	LH7
3	RH6	RH10
4	RH2(8a , b)	RH2(8c , d)
5	RH1(8a)	RH1(8c)
6	RH1(8b)	RH1(8d)
7	LH2(10a , d)	LH2(10b , C)
8	LH1(10a)	LH1(10c)
9	LH1(10d)	LH1(10b)
10	RH1(8b)	RH1(8d)
11	RH1(8b)	RH1(8d)
12	RH1(8b)	RH1(8d)
13	RH1(8b)	RH1(8d)
14	RH1(8d)	RH1(8b)



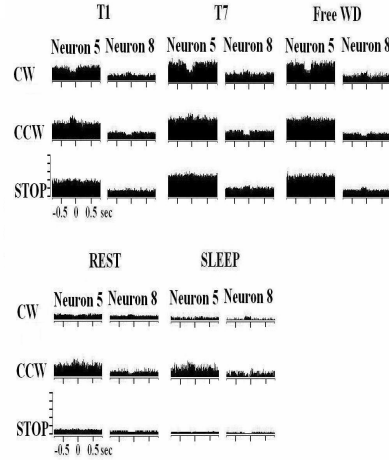
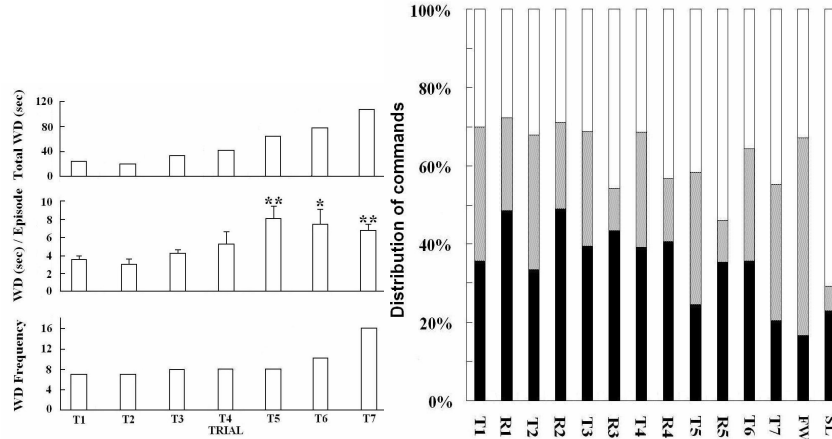
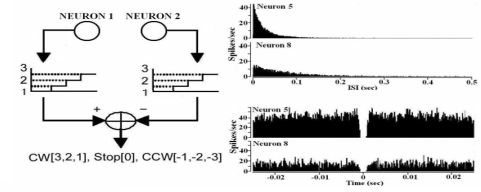
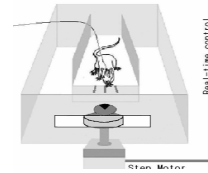
T5



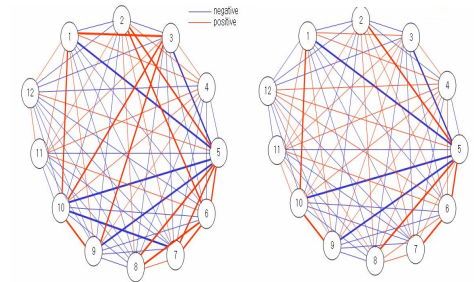
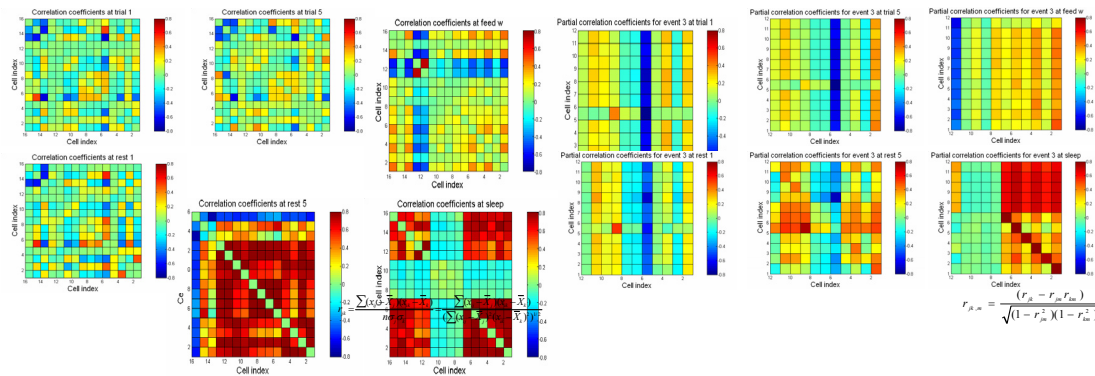
T6



- (1) **BCI system using spontaneous activity of SI cortex for rats to quench thirst?**
- (2) **without using sensory input and muscle movement?**
- (3) **minimal number of neurons for a BCI?**
- (4) **efficiency of BCI dependent on trial numbers?**
- (5) **operating without motor cortex?**
- (6) **specific to animal's intention?**
- (7) **What kind of SI neurons are good for BCI?**



	Neuron 5	TST 1	Neuron 8	TST 2	Command
T1	20.06 (212.46)	1	16.56 (73.04)	2	1 CW
	44.88 (41.58)	3	7.84 (57.43)	1	2 CCW
	36.53 (383.84)	2	14.84 (451.67)	2	1 STOP
T7	24.85 (287.07)	1	22.11 (131.03)	3	2 CW
	54.33 (71.14)	3	10.45 (109.84)	2	1 CCW
	51.36 (580.26)	3	23.03 (756.13)	3	1 STOP
REST	6.42 (0)	0	9.57 (0)	1	1 CW
	31.70 (0)	2	4.98 (0)	0	2 CCW
	7.55 (0)	0	2.69 (0)	0	1 STOP
SLEEP	4.00 (-37.69)	0	7.08 (-26.02)	1	1 CW
	24.11 (-23.94)	1	2.58 (-48.19)	0	1 CCW
	2.71 (-64.11)	0	0.61 (-77.32)	0	1 STOP
Free WD	25.73 (300.78)	1	20.63 (115.57)	2	1 CW
	52.47 (65.52)	3	8.86 (77.91)	1	2 CCW
	46.74 (519.07)	3	20.32 (655.39)	3	1 STOP



[Summary] 전전두엽 신경세포 2개의 활동을 활용한 실시간 1차원운동 기계의 의지적 조절

18 Experiments were done.

- 1) 최대 BCI 효율: 23%
- 2) 세포쌍 간의 correlation coefficient와는 무관
- 3) PSD, Correlation Dimension의 변화량 분석, Burst Analysis에서 BCI 효율성과 상관관계를 보임
- 4) 효율성의 증가는 물을 담은 원반을 쥐 앞으로 가져오는 빈도 수, 미세조절기간 의 증가에 의존

Relationship Analysis

	T1TW	T1F	T1AW	TLTW	TLF	TLAW	dTW	dF	dAW	%dTW	%dF	%dAW
s3	22.67	18	4.53	15.6	13	4.318	-7.08	-5	-0.2	-31.2	-27.78	-4.75
s18	21.53	18	4.31	20.54	22	3.36	-0.99	4	-0.95	-4.6	22.22	-22.04
s6	16.95	26	2.35	21.5	29	2.671	4.57	3	0.32	26.96	11.538	13.85
s7	16.57	25	2.39	20	28	2.567	3.39	3	0.18	20.46	12	7.539
s12	15.07	17	3.19	21.52	32	2.42	6.45	15	-0.77	42.8	88.235	-24.138
s15	8.96	18	1.79	6.83	11	2.236	-2.13	-7	0.446	-23.77	-38.889	24.916
s1	8.61	17	1.82	12.1	24	1.811	3.46	7	0	40.19	41.176	-0.67
s16	8.46	17	1.79	11.39	18	2.277	2.93	1	0.487	34.63	5.88	27.2
s11	4.61	11	1.5	7.43	15	1.782	2.82	4	0.282	61.17	36.36	18.8
s9	3.11	4	2.8	19.11	18	3.822	16	14	1.022	514.47	350	36.5
s17	2.89	8	1.3	2.39	7	1.228	-0.5	-1	-0.072	-17.3	-12.5	-5.538
s5	2.83	7	1.46	8.67	21	1.486	5.84	14	0.03	206.4	200	1.961
s8	2.57	8	1.16	9.15	19	1.733	6.58	11	0.58	256	137.5	49.65
s14	1.9	5	1.37	7.02	17	1.579	5.12	12	0.209	269.47	240	15.25
s10	1.74	5	1.25	12.44	26	1.723	10.7	21	0.473	614.94	420	37.84
s13	1.62	4	1.47	2.1	4	1.883	0.48	0	0.413	29.63	0	28.095
s2	0.56	2	1	26.8	29	3.119	26.23	27	2.12	4684	1350	211.9
s4	0.56	2	1	5.78	13	1.599	5.22	11	0.6	932.1	550	59.94

T1TW vs. T1F: $r=0.858, p<0.001$

TLTW vs. TLF: $r=0.814, p<0.001$

dTW vs. dF: $r=0.879, p<0.001$

%dTW vs. %dF: $r=0.957, p<0.001$

T1TW vs. T1AW: $r=0.879, p<0.001$

TLTW vs. TLAW: $r=0.701, p=0.001$

dTW vs. dAW: $r=0.741, p<0.001$

%dTW vs. %dAW: $r=0.945, p<0.001$

T1F vs. T1AW: $r=0.56, p=0.016$

dF vs. dAW: $r=0.447, p=0.063$

%dF vs. %dAW: $r=0.905, p<0.001$

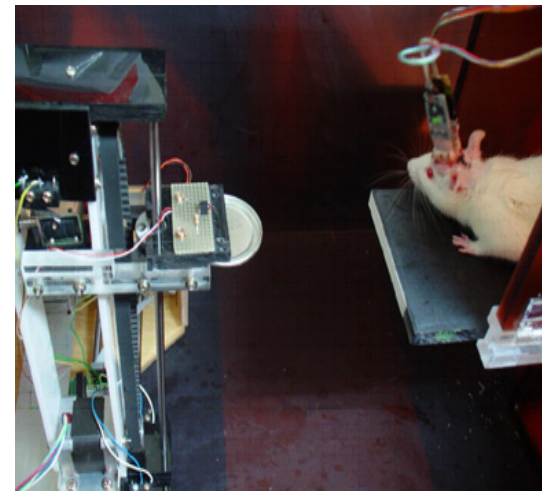
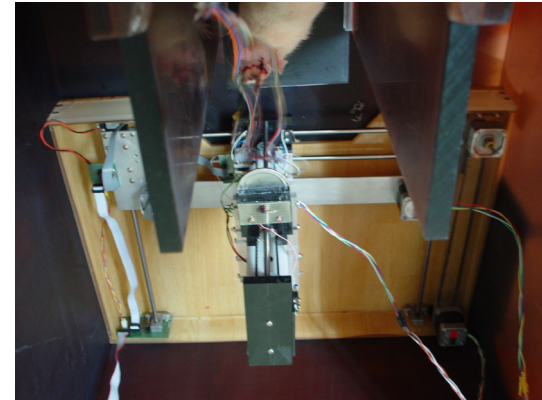
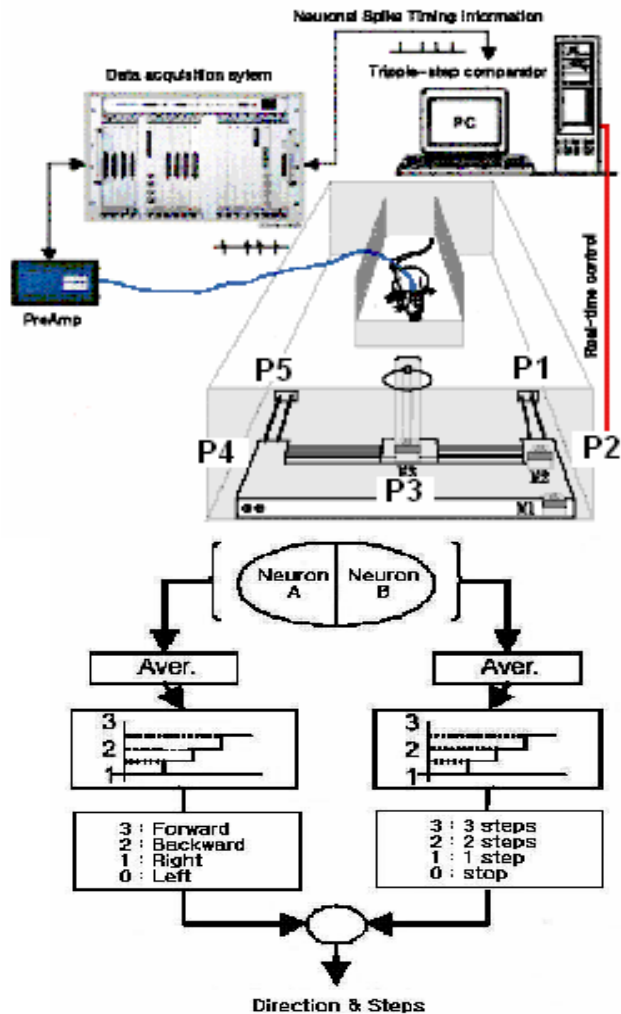
Summary for the 1D movement control using CA1 Hippocampal single neuron pair

19 Experiments were done.

- 1) Maximum efficiency of the 1D: 21%
- 2) Correlation coefficient of CA1 neuron pair vs. Efficiency = not related
- 3) PSD, Change of correlation dimension vs. Efficiency = significantly related.
- 4) Increase of the efficiency: related to the frequency of the accessing water disk

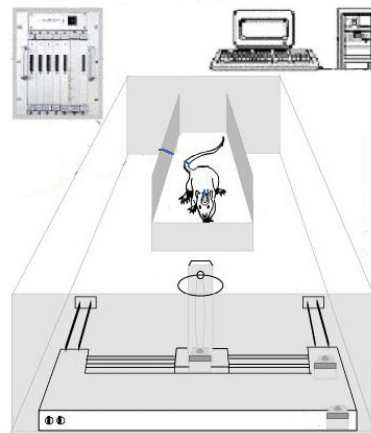
	T1TW	T1F	T1AW	TLTW	TLF	TLAW	dTW	dF	dAW	%dTW	%dF	%dAW
Subject17	21.2	22	3.46	25.7	15	6.18	4.5	-7	2.72	2.72	-31.8	78.6
Subject12	21.1	13	5.84	8.2	12	2.46	-12.9	-1	-3.38	-61.1	-7.7	-57.8
Subject19	18.3	14	1.93	13.9	17	4.16	-4.4	3	2.23	-24	21.4	115.5
Subject2	16.7	10	5.99	24	16	5.39	7.3	6	-0.6	43.84	60	-10
Subject11	15.2	13	4.21	15.3	14	3.93	0.1	1	-0.28	0.65	7.6	-6.65
Subject18	12.8	21	0.95	4.92	10	1.77	-7.88	-11	0.82	-89.2	-52.3	86.3
Subject8	12.6	16	2.8	23	26	3.179	10.4	10	0.38	82.08	62.5	13.54
Subject3	11.1	9	4.45	12.8	10	4.6	1.66	1	0.15	14.9	11.11	3.37
Subject10	10.1	14	2.59	4.1	2	7.4	-6	-12	4.81	-59.4	-85.7	185.7
Subject1	8.19	9	3.27	16.2	12	4.853	7.99	3	1.58	97.56	33.33	48.4
Subject14	8.1	9	3.22	7	14	1.8	5.9	5	-1.42	72.8	55.5	-44
Subject16	7.6	9	3.03	0.6	1	2.13	-7	-8	-0.9	-92	-88.8	-29.7
Subject7	6.39	13	1.7	1.94	4	1.8	-4.5	-9	0.1	-69.6	-69.23	5.882
Subject9	5.4	3	6.47	7.3	9	2.93	3.6	6	-3.54	32.33	200	-54.7
Subject13	3.2	6	1.9	1.8	5	1.3	-1.4	-1	-0.6	-43.7	-16.6	-31.5
Subject4	2.34	4	2.1	11.9	15	2.85	9.54	11	0.75	407.7	275	35.7
Subject15	1.8	4	1.63	7.1	16	1.6	5.3	12	-0.03	294.4	300	-1.84
Subject5	1.41	3	1.69	13.7	26	1.895	12.3	23	0.21	870.9	766.67	12.2
Subject6	0	0	0	25.2	23	3.93	25.2	23	3.93			

2-D Movement Control



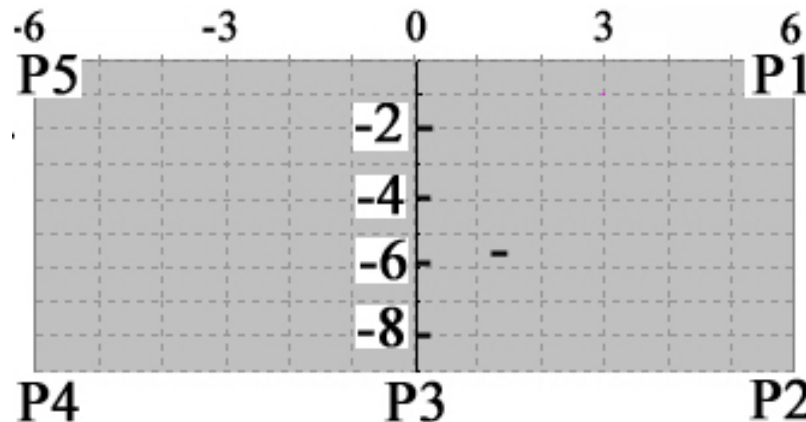
$$\begin{aligned} (F) &\geq M + 0.5xSD + 1 \\ (B) &= M \sim M + 0.5xSD \\ (L) &= M - 0.5xSD \sim M - 1 \\ (R) &\leq M - 0.5xSD - 1 \end{aligned}$$

$$\begin{aligned} \text{Start} &\geq M - 0.5xSD \\ \text{Stop} &\leq (M - 0.5xSD) - 1 \end{aligned}$$



N1 N2
F
B
L
R
START
STOP

in X, Y coordinate, n = 60,
P1: 5.8 ± 0.1 , -0.3 ± 0.1
P2: 5.9 ± 0.1 , -8.1 ± 0.1
P3: 0.1 ± 0.2 , -8.3 ± 0.1
P4: -4.9 ± 0.1 , -8.5 ± 0.1
P5: -4.6 ± 0.2 , -0.03 ± 0.03



Real-time Control of 2-Dimensional Machine Movement

Capable to access target object from 5 different positions

Target
position 5



Target
position 1

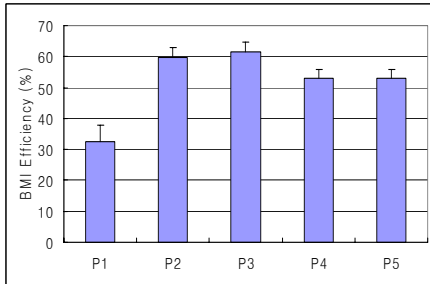
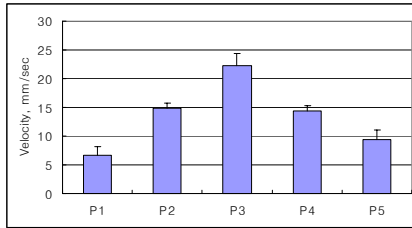
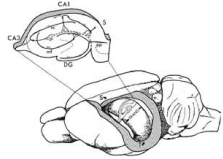
Rat. No.19
체성감각신피질
2 Neurons used
2b (32.76 Hz)
5d (45.80 Hz)
M2 algorithm
Total 5 Trials

Target
position 4

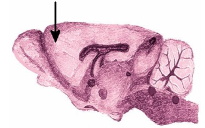
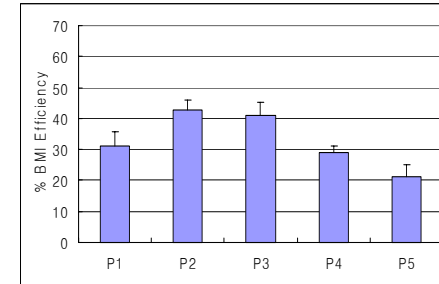
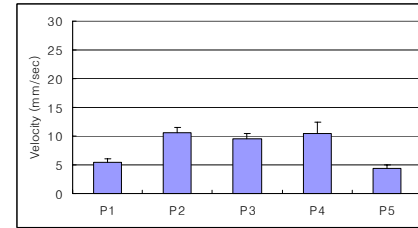
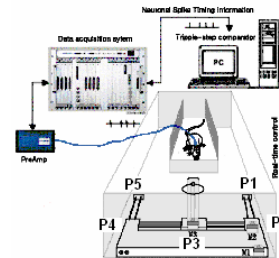
Target
position 3

Target
position 2

CA1



PFC

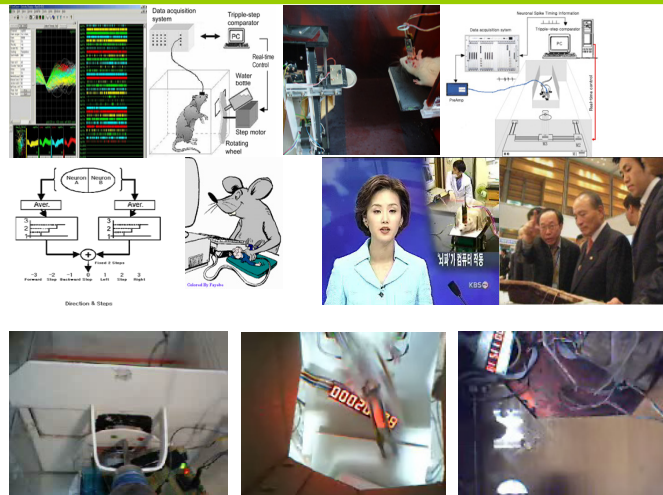


Correlation between the efficiency of TG tasks and commands

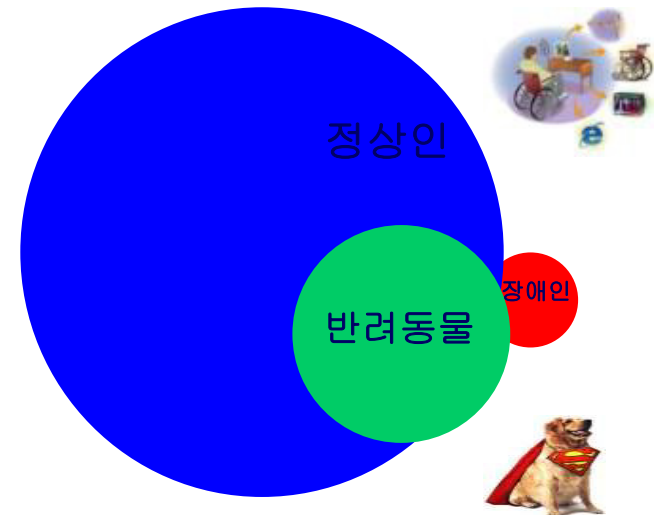
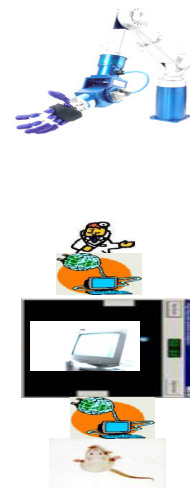
P1 related to the % L, $(r)=-0.7786$
P2 the ratio between L+F and R+B, $(r)=0.6155$
P3 inversely related to the F, $(r)=0.6976$
P4 the ratio between R+F and L+B, $(r)=0.6211$
P5 related to the % R, $(r)=0.7046$

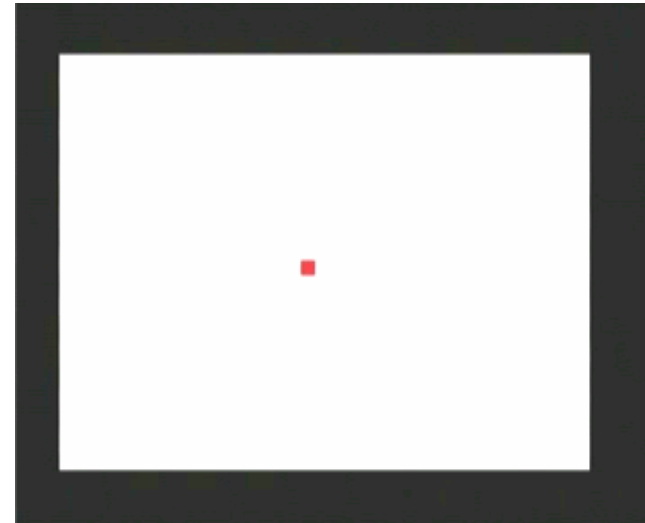
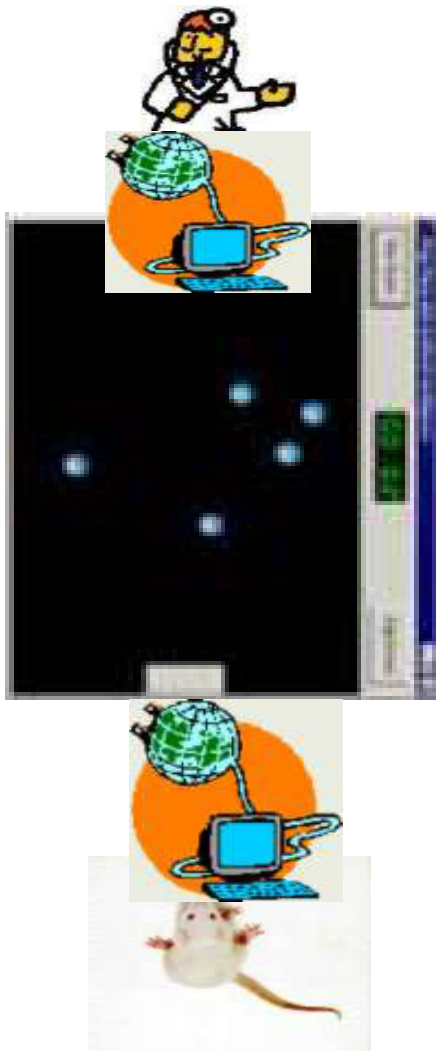
P1 inversely related to the R/L ratio $((r)=-0.6351)$
P2 the ratio between L+F and R+B $((r)=0.5748)$
P3 inversely related to the R/L $((r)=-0.5680)$
and positively correlated to the F/B $((r)=0.6053)$.
P4 the ratio between R+F and L+B $((r)=0.6204)$
P5 positively related to the R/L ratio $((r)=0.5665)$

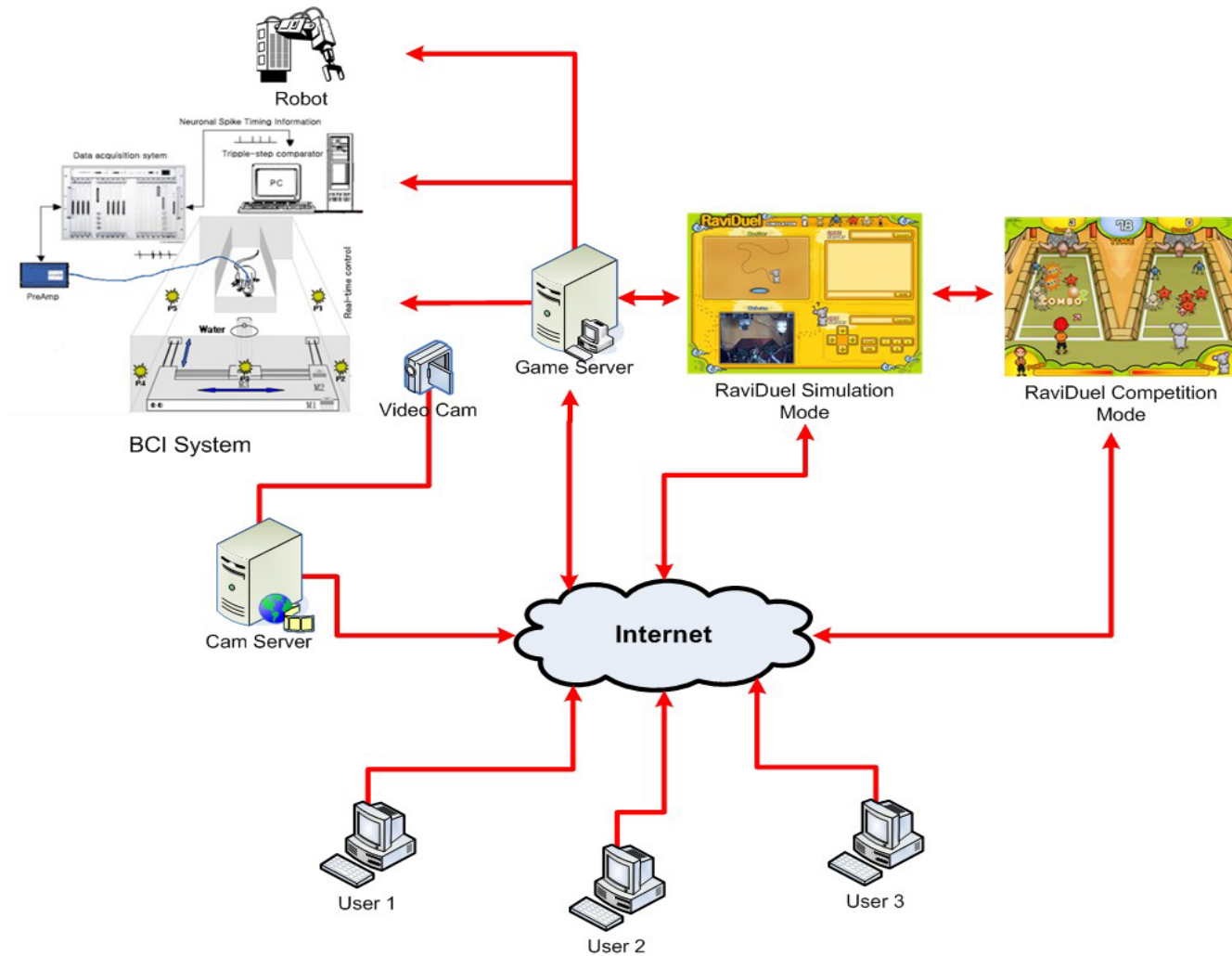
1. “단일신경신호 암호화(encoding) 방법”에 기초한 BMI 연구를 쥐를 실험동물로 하여 수행하였음.
2. 운동의 뇌가 아닌 감각 뇌의 자발적인 신호를 사용함으로 운동의 뇌가 손상된 환자에게도 적용가능.
3. 해마와 전전두엽 등에서도 X, Y 축의 2차원 실시간 운동제어 성공.
4. 2개의 단일신경세포 만으로 성공.
5. 뇌의 침습 정도를 극소화 한 상황에서도 2차원 컴퓨터화면 조정 가.
6. 논문발표, 특허 및 기술이전 완료



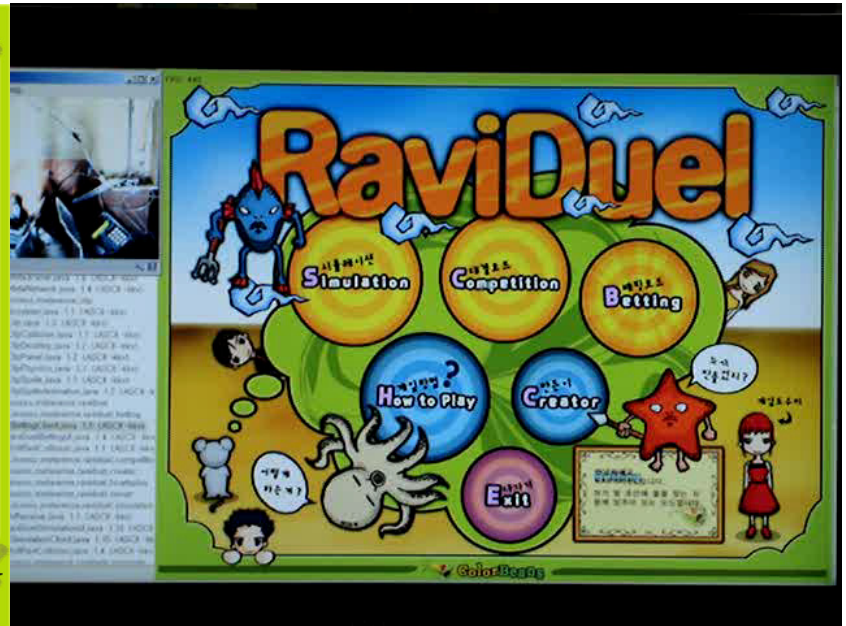
1. 쥐를 활용한 1단계연구결과를 기반으로 반려동물인 개에서 수행함으로써 연구수행이 용이.
2. 신경신호 Encoding 기법으로 수행함으로써 운동신경세포 외의 타 신경세포들을 BMI에 활용.
3. 인터넷에 기반해서 다양한 로봇의 원격제어가 가능함으로 단순한 로봇들의 기능을 합목적으로 연합 실행시킬 수 있음.
4. 반려동물을 Super Companion Dog으로 진화시킴으로써 인간과 새로운 정보소통이 가능하게 함.
5. fNIRS BMI를 활용함으로써 범용성 확보 및 신산업 창출.



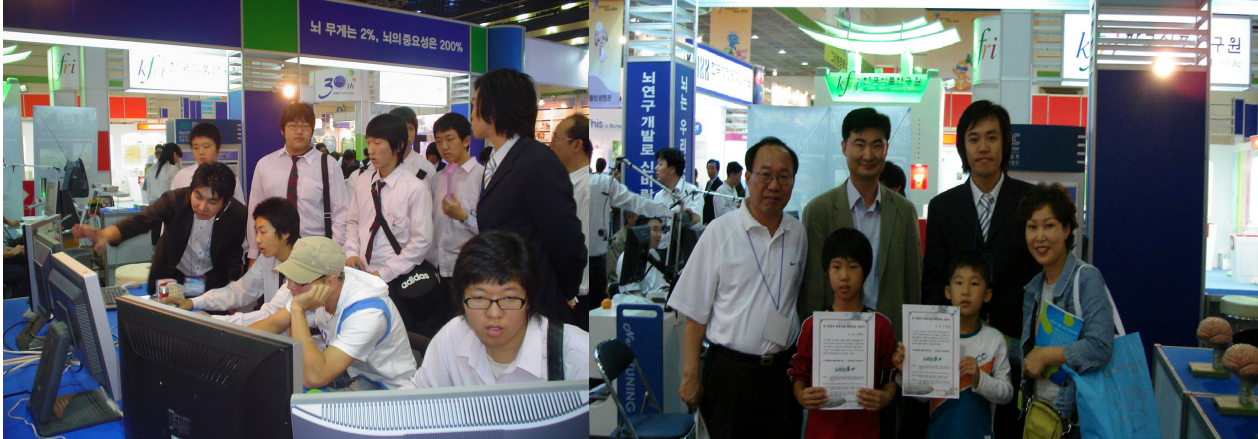




A window of the game, *RaviDuel*



A window of a session of the game, *RaviDuel+*.



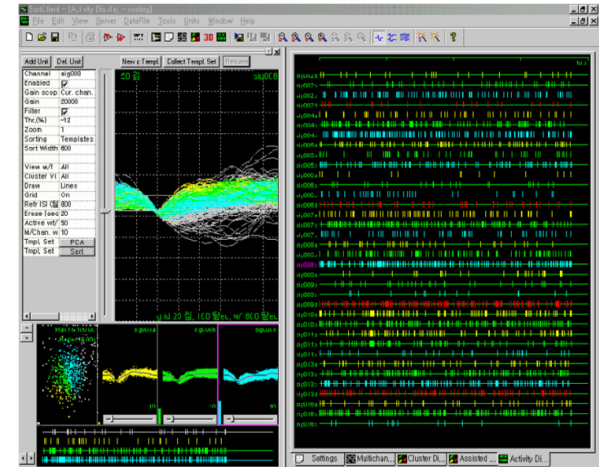
Extra-cellular many single neuron recording from pre-frontal cortex and CA1 hippocampus from dogs

I. Experimental Animal and surgery



- ① Dogs: Yorkshire terrier (1.6~2.7 Kg)
- ② Head plug & Microelectrode
- ③ Recording electrode (8~16 channel) implantation
- ④ Vocal cord surgery

II. Multi-channel single neuron recording



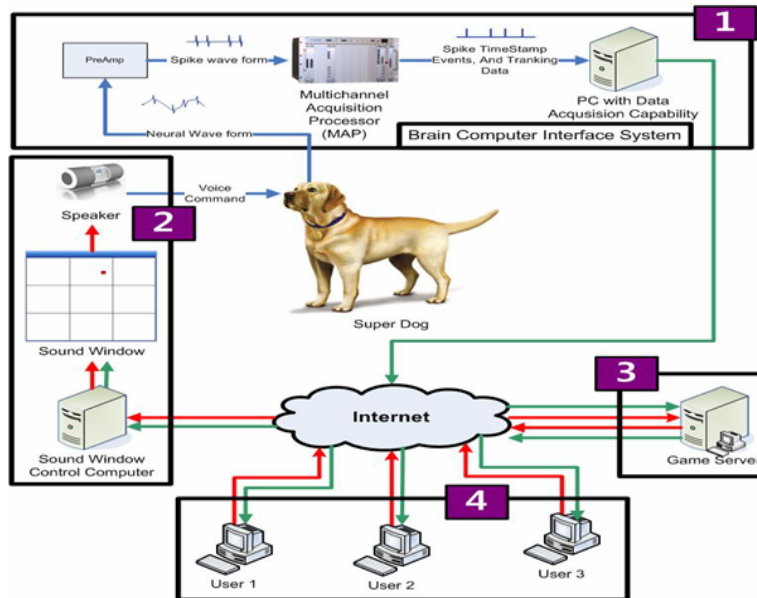
- ① Dog's brain map
- ② Plexon data acquisition system
- ③ Single unit isolation

뇌-컴퓨터 접속 슈퍼독



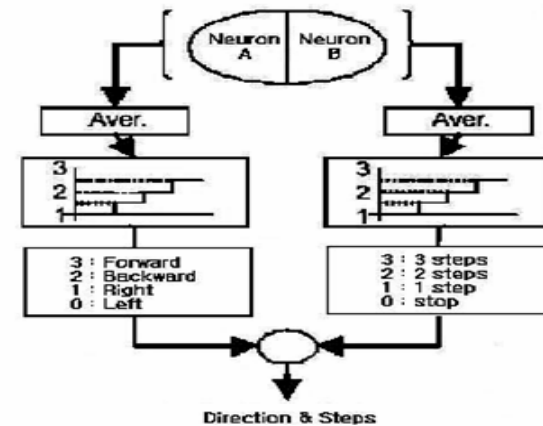
A BCI system for 2-dimensional movement control

I. BCI System Digram



- ① Sound generation through a soundwindow program for feedback to the dog to recognize navigational outcome.
- ② 2-Dimentional movement control to get food reward
- ③ Internet connection to play game with people

II. Command generation Algorithm

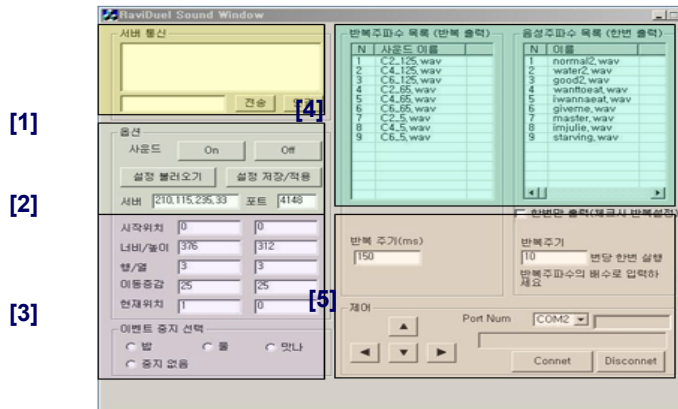


Neuron A for direction value
Neuron B for step value

- ① Neuron A's Activity → Triple-threshold Algorithm → 4 commands (Forward, Backward, Left & Right).
- ② Neuron B's Activity → movement distance (3, 2, 1, 0 steps).
- ③ Every 200 msec

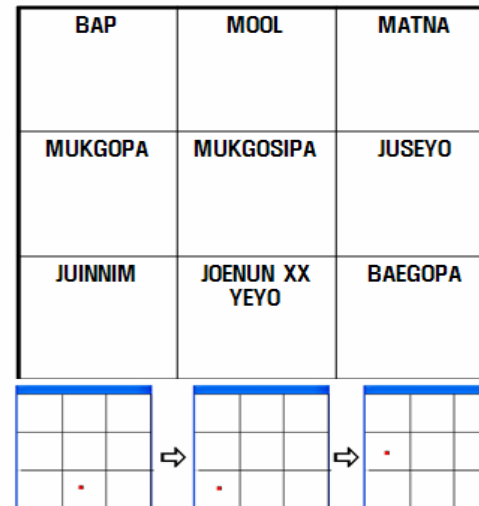
2-Dimensional Sound Window

I. Sound Window Program

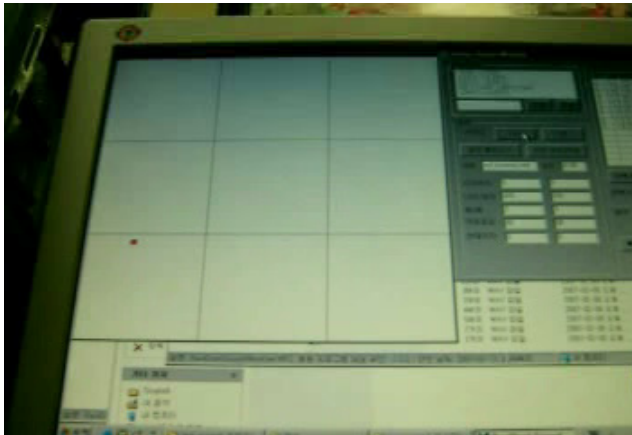


- ① Server states
- ② Control for Size & Number of the sound beeping region
- ③ Server setting and switch for sounds
- ④ Lists of sound files
- ⑤ Freequency of sound and manual control of food disk

II. Allocated human voices (n=9) on the 2-D Sound Window

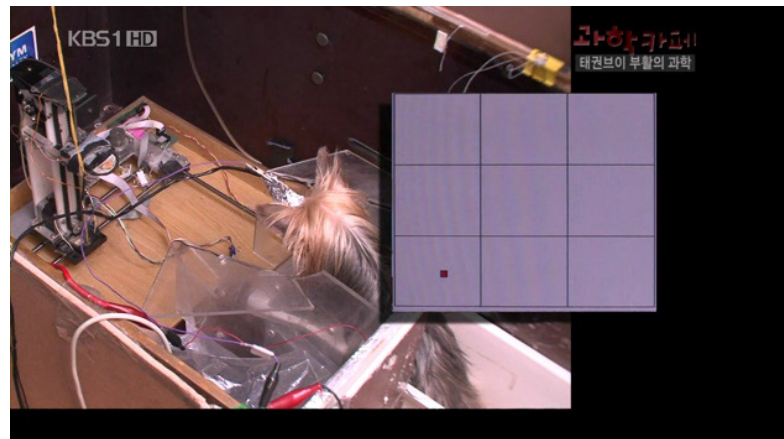


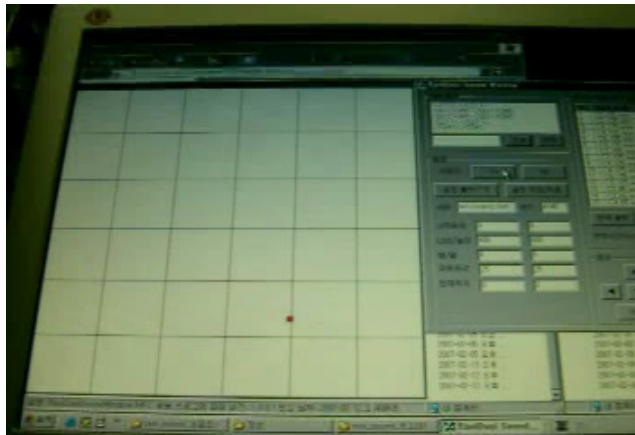
- ① Navigating red point controlled by the change of neural activity.
- ② If the red point stay in a section of the sound window, then allocated beeping sounds were generated.
- ③ If it stays in a sector more than a second, then an allocated human voice were generated.



1	2	3
4	5	6
7	8	9

밥! 밥!	물! 물! 물!	맛나! 맛나!
먹고파	먹고싶다	주세요
주인님!	나!	배고파





Korean



人 犬 伏

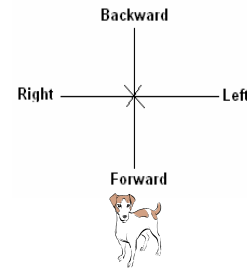
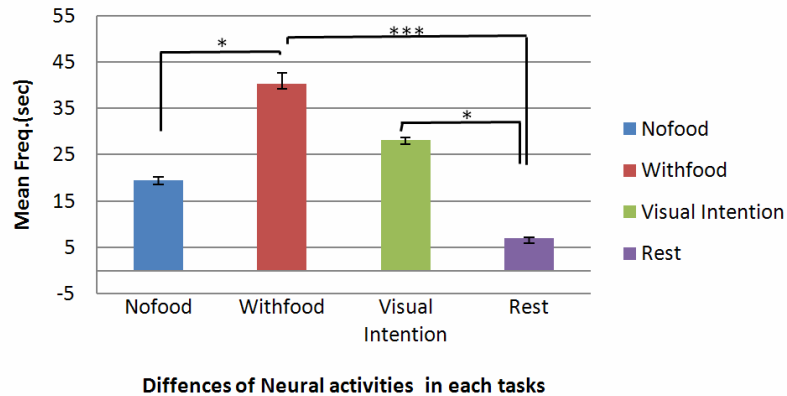
English

Chinese

Russian

Differences of Neural activities

No food , With food, V.Intention, Rest



Correlation between the duration of TG tasks and commands

P1 related to the R/L, F/B and (L+F)/(R+B) ratio ((r)=0.5485, 0.679, 0.8803 respectively)

P2 the ratio between R+F and L+B ((r)=0.5642); and R/L ratio ((r)=0.6347)

P3 strongly related to the (L+F)/(R+B) ((r)=1)

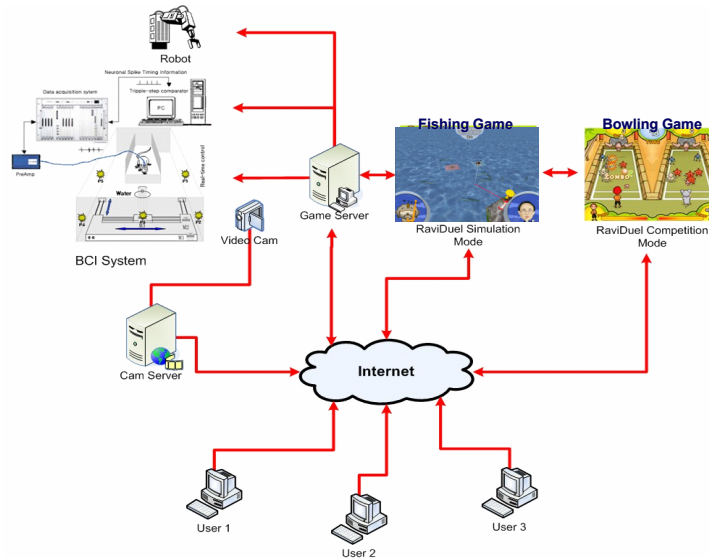
P4 the ratio between R/L ((r)=0.7175)

P5 positively related to the R/L ratio ((r)=0.7994)

Comparison	Mean Difference	q	P value
Nofood vs With food	-20.723	4.266 *	P<0.05
Nofood vs V.Intention	-8.678	1.787 ns	P>0.05
Nofood vs Rest	12.579	2.590 ns	P>0.05
With food vs V.Intention	12.045	2.480 ns	P>0.05
With food vs Rest	33.302	6.856 ***	P<0.001
V.Intention vs Rest	21.257	4.376 *	P<0.05

Fully automated Internet game between a BCI-interfaced dog and a human internet user

I. System Diagram for Internet Game b/w BCI dog and internet users

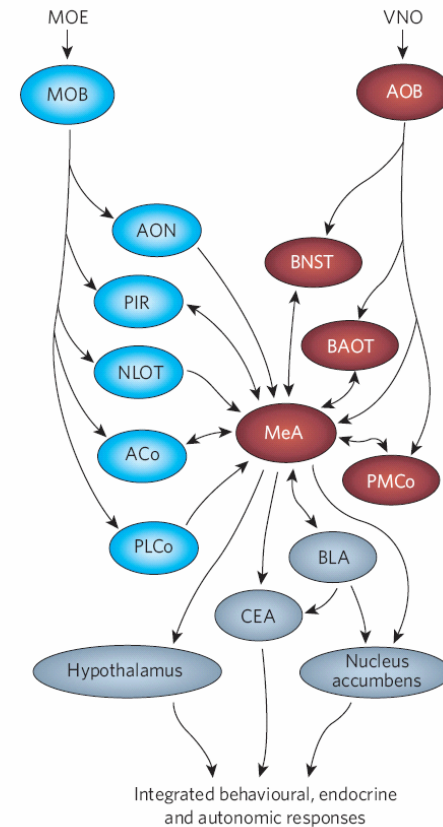
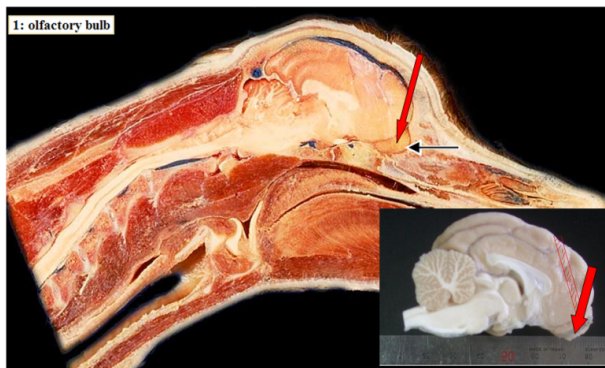


II. Automated Fishing Game

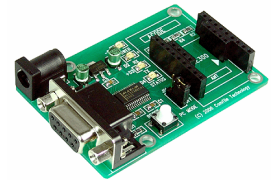
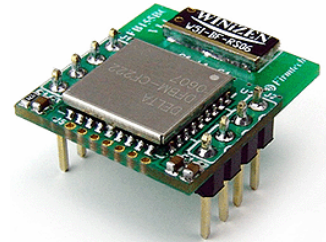
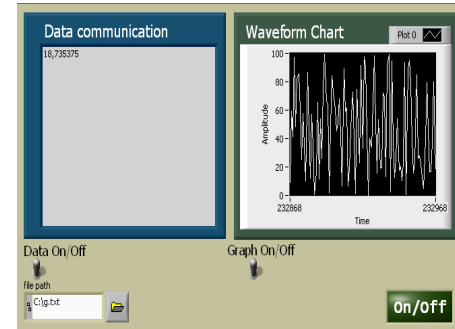
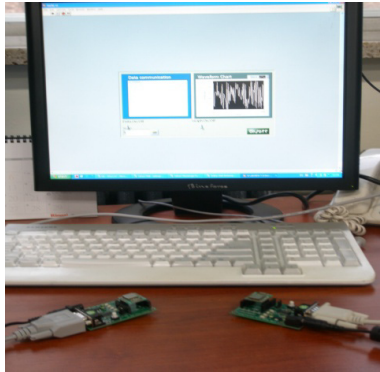


Decoding olfactory information from a dog: Medical Doc Dog for early cancer detection

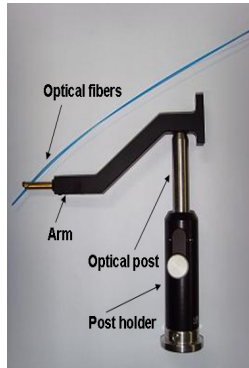
Dachshund



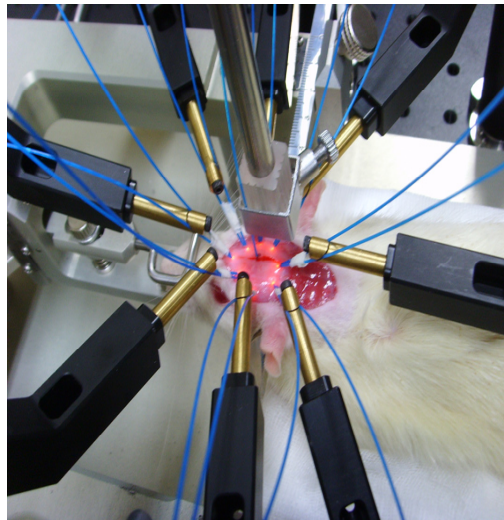
Wireless Communication & Display for freely moving BCI dog



Simultaneous recording of NIRS response and electroneural responses



**Manipulating
arm**



NIRS setup

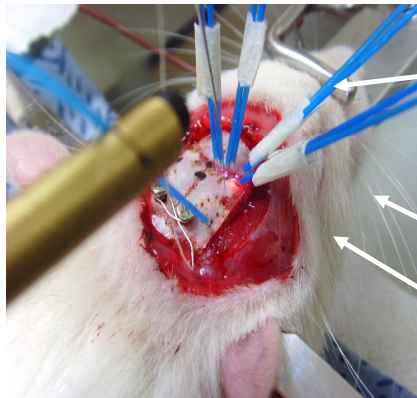
- Imagent from ISS
- 4-channel optical probe (core 400 μm)
- Light sources are 690 and 830 nm
- Sampling rate is 20.2 Hz

Electrical recording setup

- 1-channel tungsten electrode
- Sampling rate: 2000 Hz

Animal preparation

- Female Sprague-Dawley rats (250~300 g)
- Anaesthetized with urethane
- Needles of bio-stimulator are inserted in the B4 and E1 of the left whisker
- Optical fibers are placed on the skull surface (used dental cement)



**Tungsten
electrode**

Sources

Detector

BioMedical Optics Lab., Yonsei University

Super Dog의 개발: 뇌-기계 접속기술의 응용

1	2	3
4	5	6
7	8	9



밥! 밥!	물! 물!	맛나!
먹고파	먹고싶다	주세요
주인님!	나!	배고파



Development of a Dog commanding 9 human expressions using a Sound Window as an aural 2-D neuro-feedback



A fully automated internet game between a Dog and a human player

■ BMI (Brain-Machine Interface)

- 모델 : 요크셔 테리어 참견
- 전전두엽, 해마 신경세포들의 자발적 활성 → 기계제어
- 특허등록 (10-2205-0037579) 및 출원
- BMI 기술을 최초로 반려동물에 적용
- BMI 기술에 의한 반려동물 능력 Upgrade
- BMI 접속된 슈퍼독과 인간과의 의사소통
- BMI 접속된 슈퍼독에 의한 가전제품 조절
- BMI 접속된 슈퍼독에 의한 다양한 로봇 조절
- BMI 접속된 슈퍼독과 원격 인터넷 게임
- BMI 접속된 슈퍼독에 의한 냄새분별 및 보고

Published Papers

1. **IEEE-CS ICHIT 2006 V.2 600-604, Development of a Neuron Based Internet Game Driven by a Brain-Computer Interface System**
2. **Electronics Letters 2007, Vol. 43, Issue 25, 1408-1410, Development of neuronal signal mapping method for 2D encoding-based brain-computer interface system**
3. **Korea Computer Congress 2007 Vol. 34, No. 1(c) , 233-236, A Sound Window System for Online Game with Animal of Wireless Brain Computer Interface**
4. **Proceedings of HCI 2007, 780-783 A Real time Internet Game Played with a Brain-Computer Interfaced Animal**
5. **Journal of Control, Automation, and Systems Engineering 2007, Vol. 13, No. 9, 838-842, Study of Analysis of Brain-Computer Interface System Performance using Independent Component Algorithm**
6. **J. Optical Society of Korea 2007, V. 12. No. 4. Hemodynamic Responses of Rat Brain Measured by Near-Infrared Spectroscopy During Various Whisker Stimulations**

Patent

10-2005-0037579호, 2007.04.30 신경 신호 기반 제어 장치 및 신경 신호 기반 제어 방법
10-2006-0098726 신경신호에 의해 구동되는 게임장치 061011
10-2008-0107803 단일신경신호 기반 음성출력방법 081031

현재 태동기, 앞으로 세상을 바꿀 나날 주요 신기술, 앞으로 대규모의 산업시장을 형성할 것으로 예측됨.

세계적으로 권위 있는 여러 기관에서 뇌-기계 접속기술을 21세기 유망 신기술로 선정하였으며, 앞으로 거대시장을 형성할 것으로 예측함.

The New York Times



BUSINESS 2.0



- 1) '05년 8월, 국가과학기술위원회→
21개 미래 국가 유망기술 중 10번째
(Humanoid 로봇 및 뇌-기계접속)
- 2) '02년 미국 NSF, 상무성 보고서→
인간능력향상을 위한 핵심적 융합기술,
'02년 NY Times→21세기 8대
신기술 선정.
- 3) '01년 MIT Technology Review--
→21세기 10대 신기술 중 하나로 선정,
Business 2.0→세상을 바꿀 8
대 신기술로 선정.



장애인



정상인?

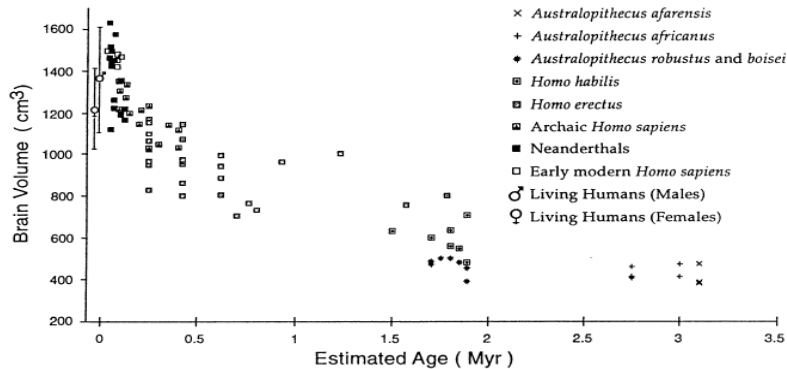


FIG. 4. Brain size (in cm³) plotted against time (Myr) for specimens attributed to Hominidae.

