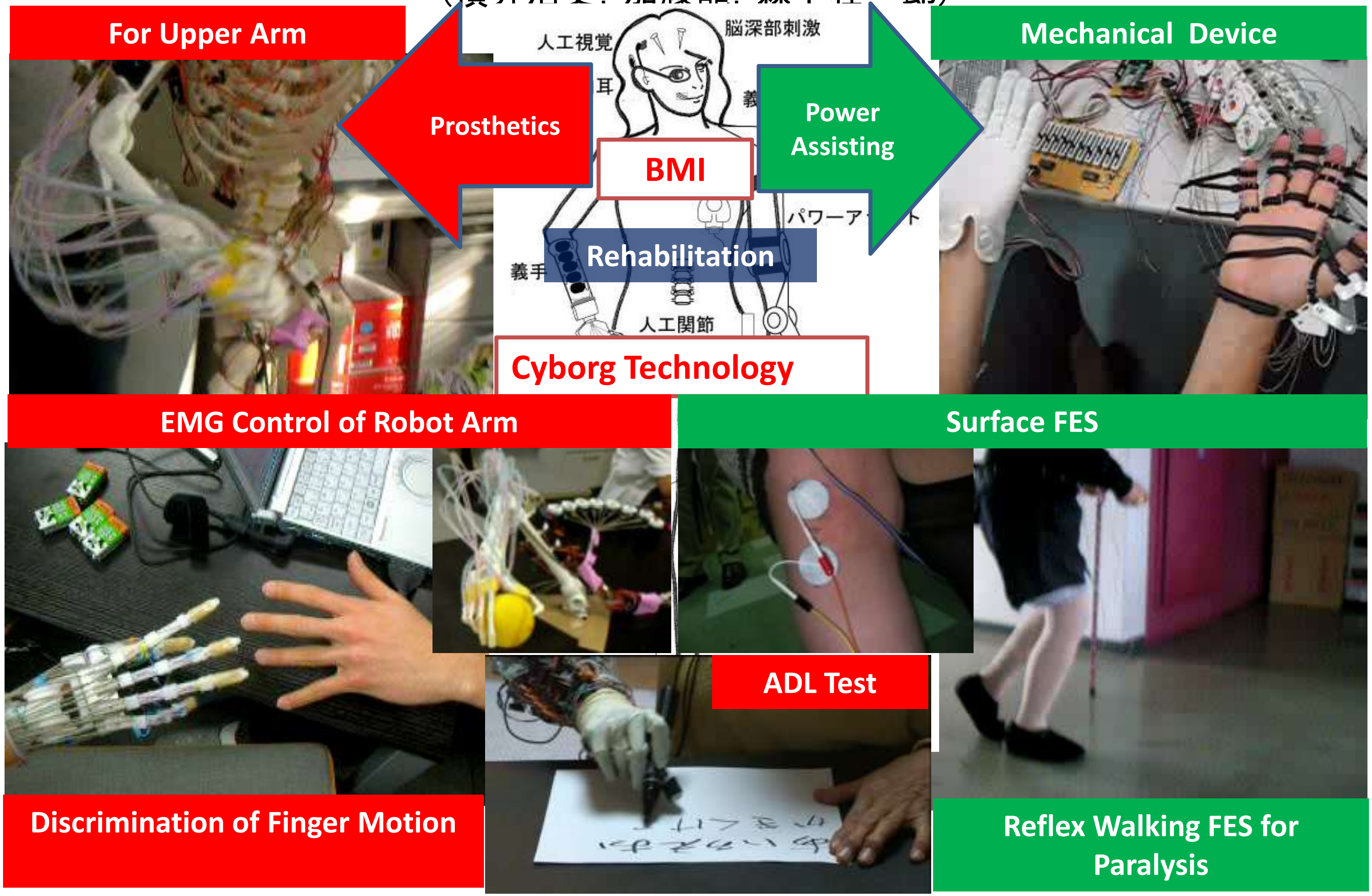
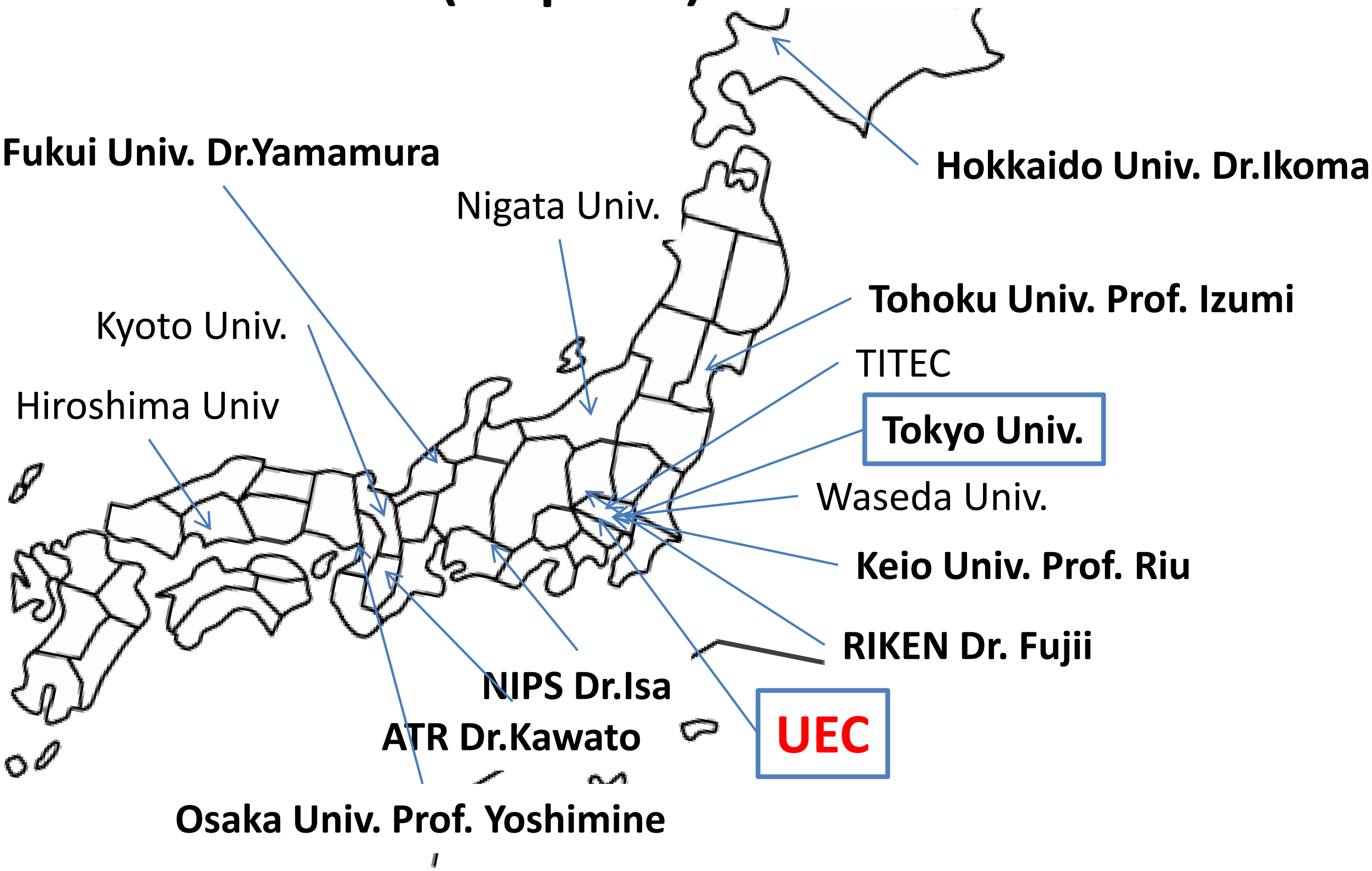
電気通信大学　知能機械
東京大学　情報学環

Human Interface Lab
ヒューマンインターフェースLab

(横井浩史，加藤龍，森下壮一郎)

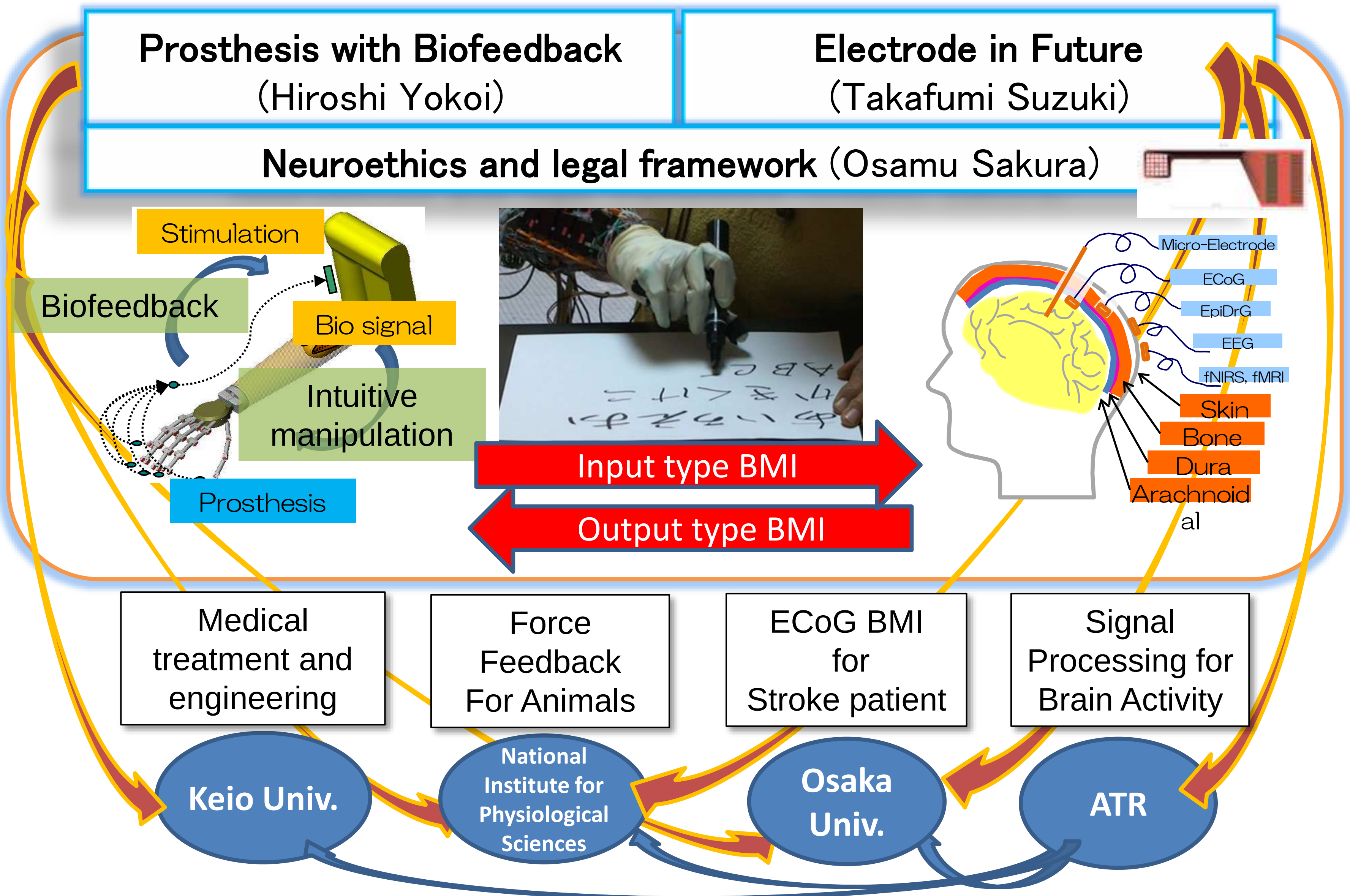


Research Map on Robotics Prosthesis (Japan)

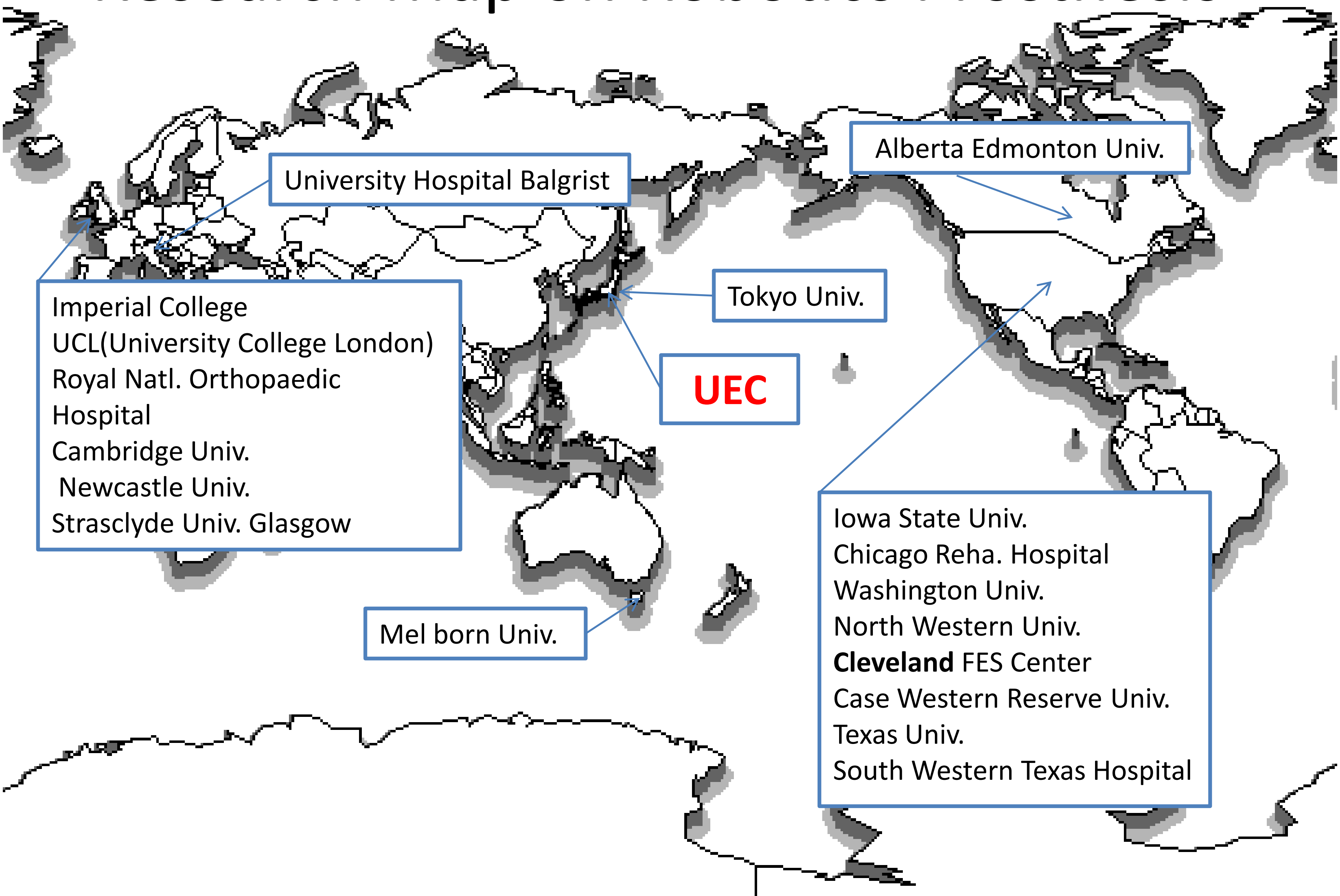


Input and Output Devices and Ethics for BMI

Tokyo Univ. in Sub. A



Research Map on Robotics Prosthesis



人と機械の融合を目指すシステム

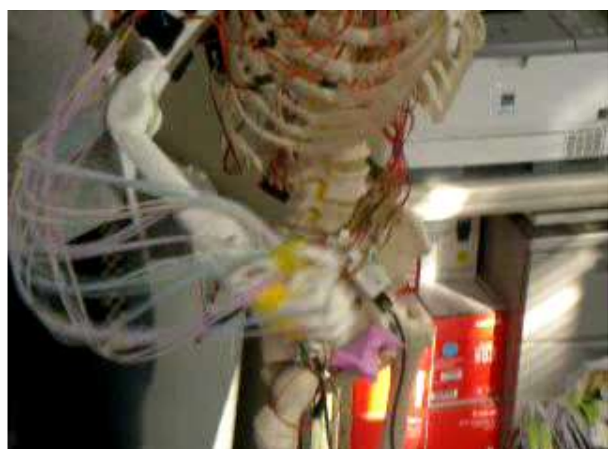
パワーアシスト

義手研究

2009 Hand for paralysis

2005 Hand for Adult

2006 Reflex walking assist



2010 Hand and Arm

2009 Hand for Child

Principle of this Lab

Intelligence is in our Body

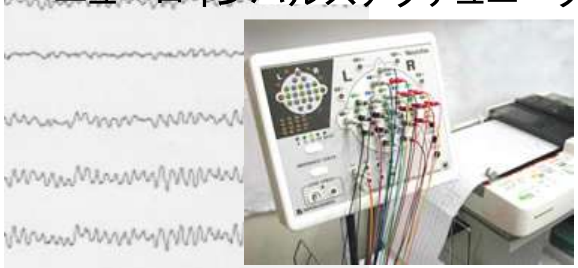
We don't need so much intelligence and muscles only to walk.

Sept 2001

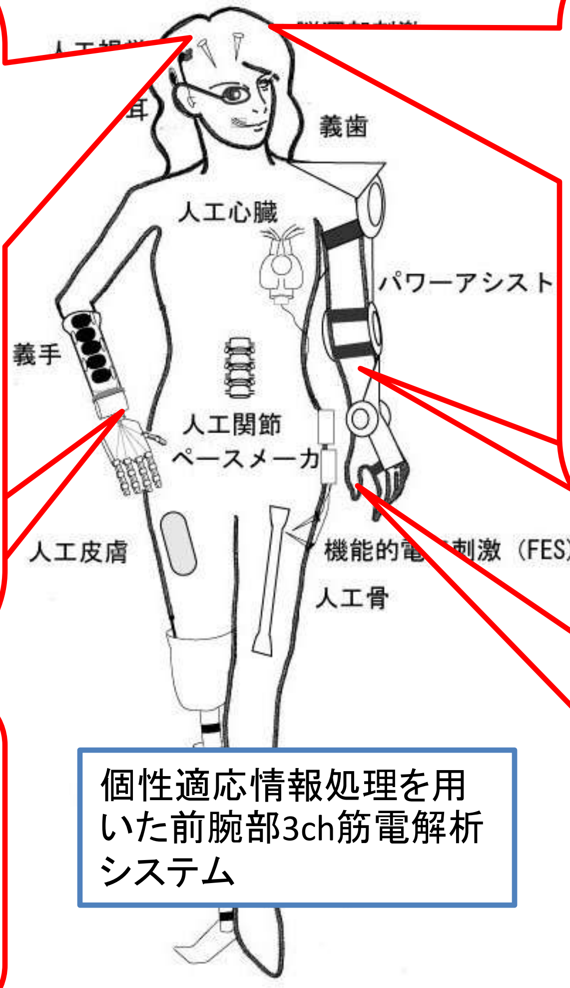
Instruments for BMI Studies

EEG計測システム

ニューロインパルスアクチュエータ

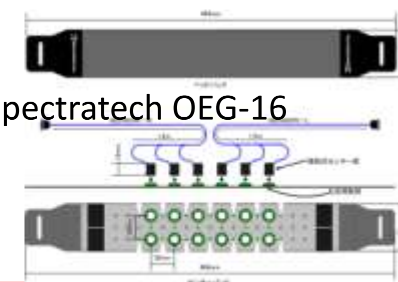


48c日本光電
全脳の頭皮上電気活動を計測



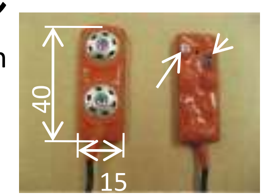
近赤外光イメージング装置

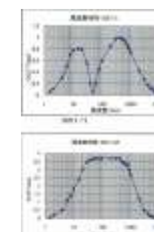
島津製作所
Force3000(8)



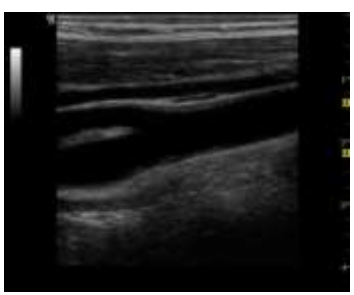
Spectratech OEG-16

EMG計測システム160ch
全身の筋活動計測





超音波診断装置



内臓・筋活動を計測可能

個性適応情報処理を用いた前腕部3ch筋電解析システム

皮膚インピーダンス計測用LCRテスター

その他，電動装具，電動車椅子，
NAC3Dモーションキャプチャ16ch，

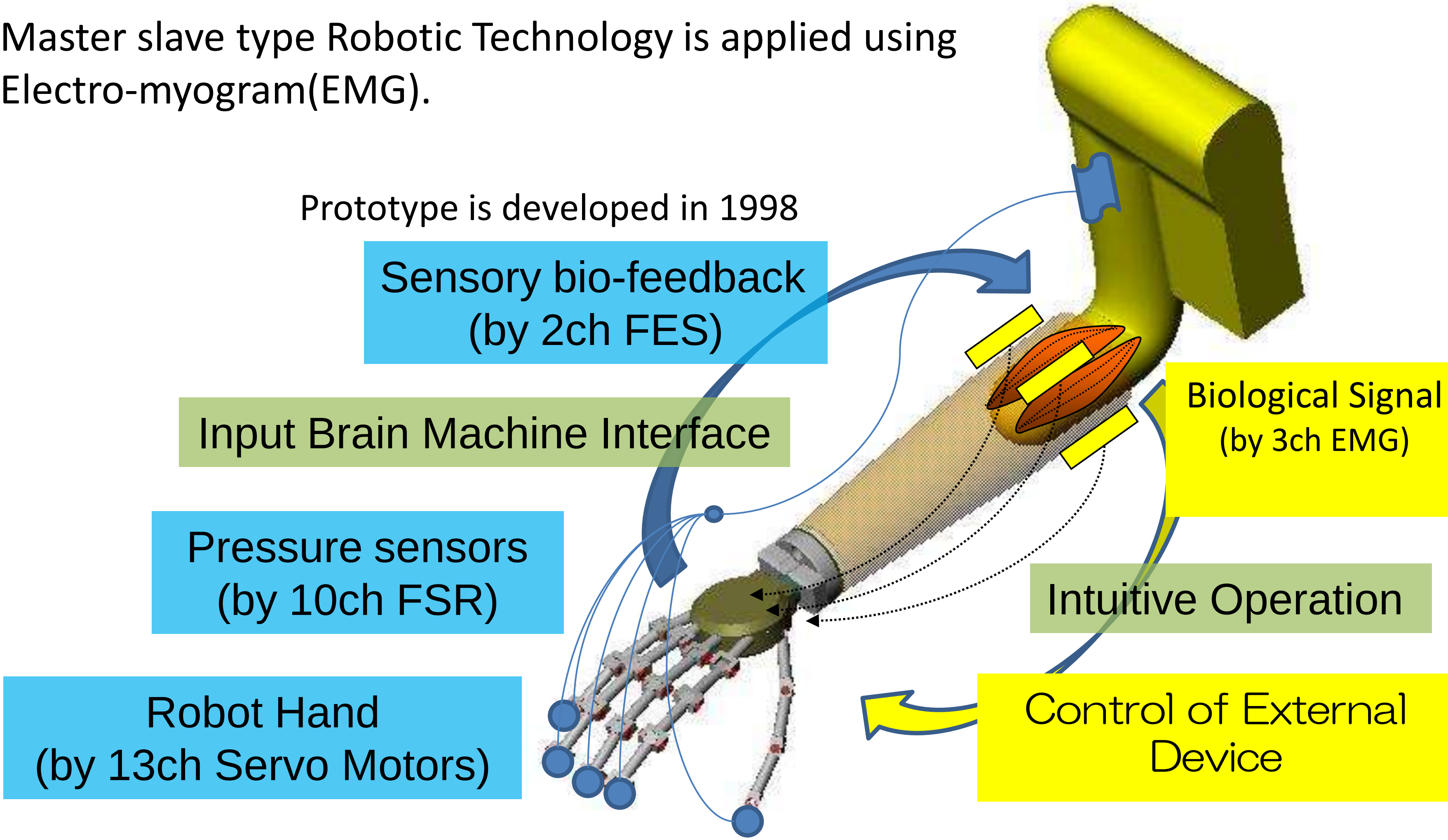
脳・神経・身体の活動に関する計測設備および，応用研究用の既存設備

Spectrum of Researches

- Adaptable EMG Prosthetic Hand
- Power Assist Device
- Functional Electric Stimulation
- Reflex Walking Assist
- Power Suits
- Image Processing for Animals Tracking

Robotics Approaches for EMG Prosthetic Hand with Bio-feed back

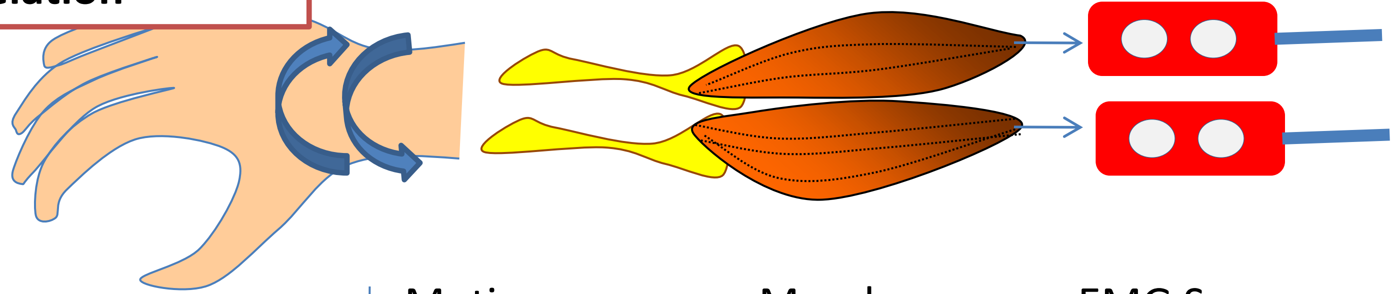
Master slave type Robotic Technology is applied using Electro-myogram(EMG).



Difficulties of EMG Classification

Functional Relation among EMG and Motion

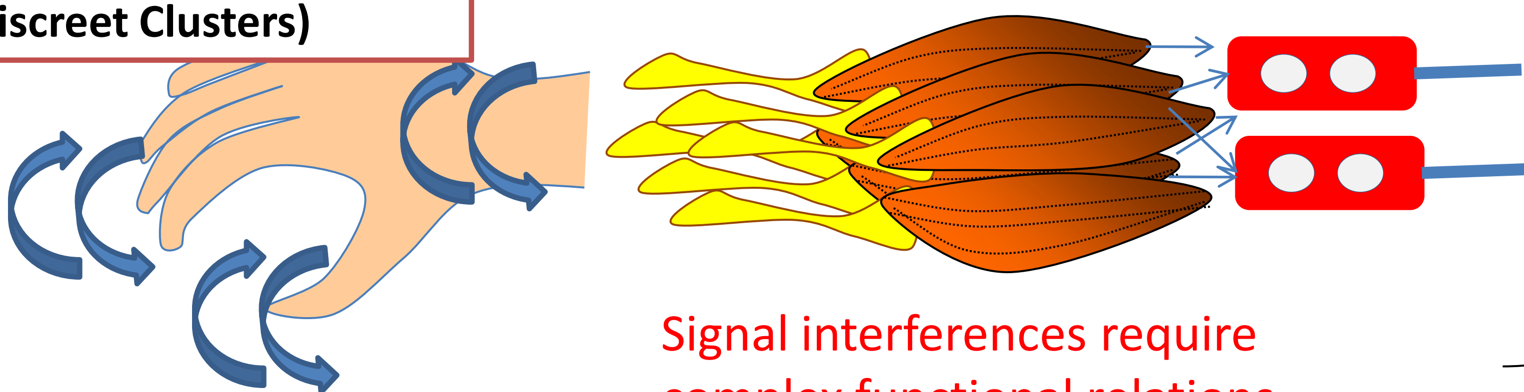
Linear Relation



	Motions		Muscles		EMG Sensors
Over restraint	–				+
Linearly Independent	N	:	N	:	N
Irregular	+		+		–

Easy Electric Circuit

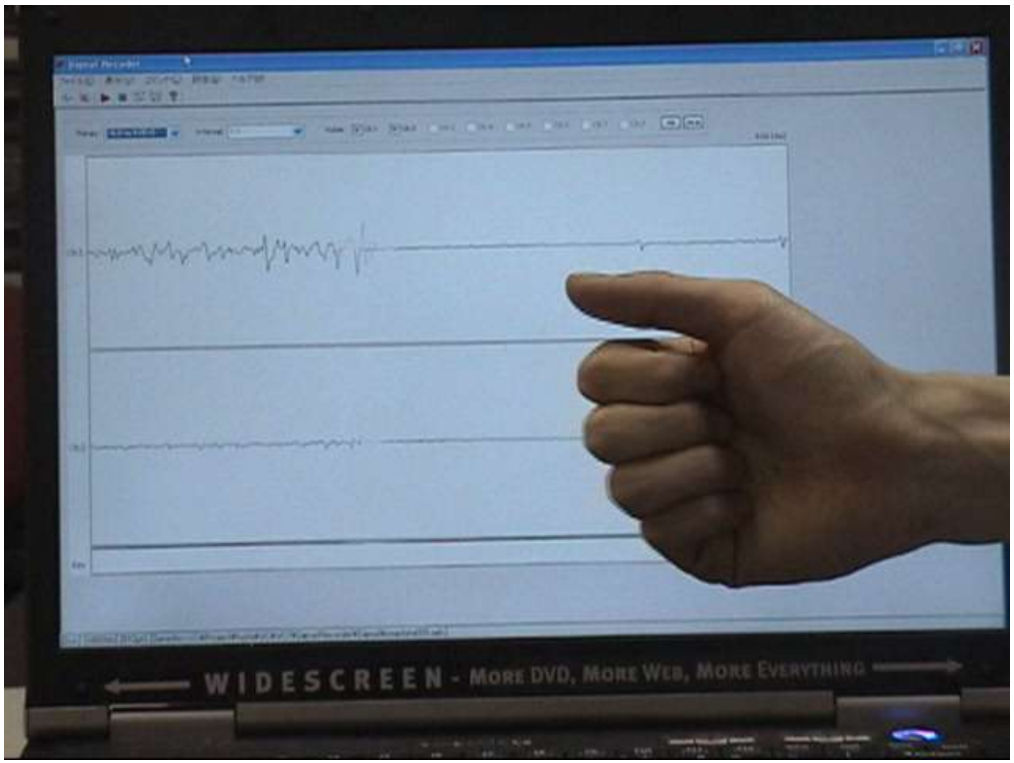
Non Linear Relation (Discreet Clusters)



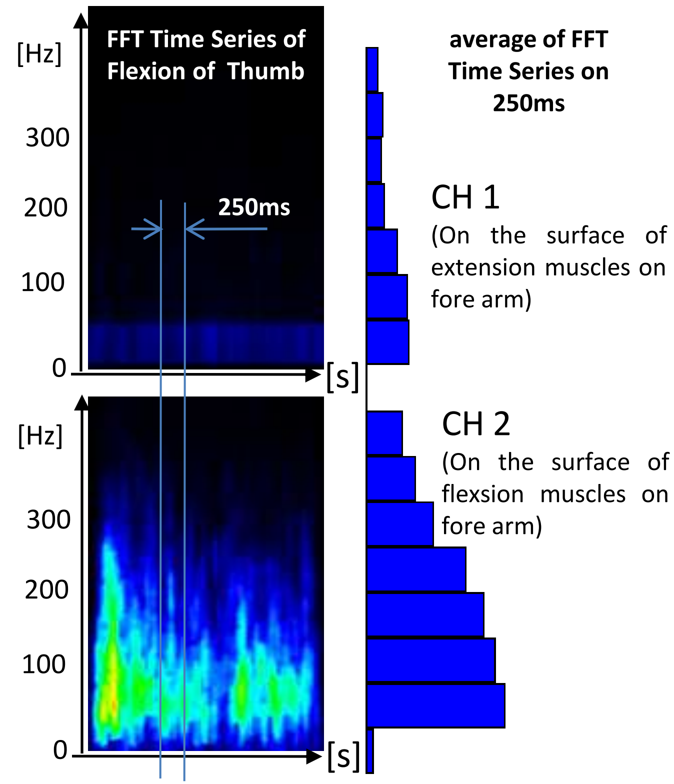
Signal interferences require complex functional relations

Needs Computation

Extraction of Human Intention by EMG

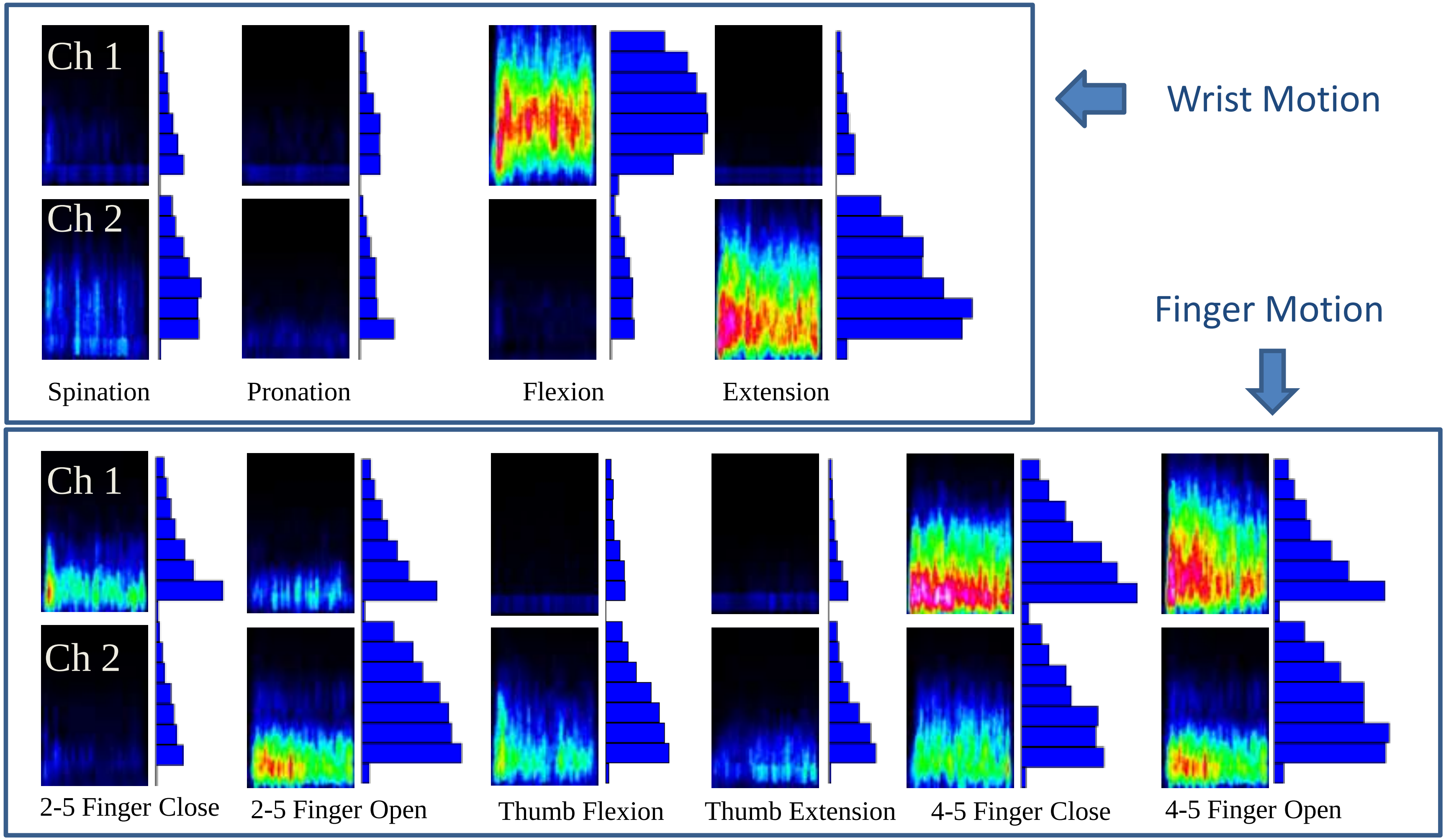


EMG Signal



Spectrum Analysis of Flexion of Thumb (Finger No.1)

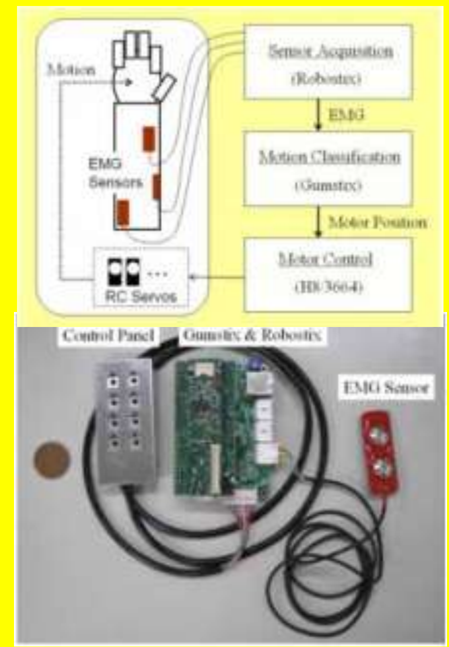
Spectrum Analysis of EMG Signal of Wrist and Finger Motion



The different motion produce different histogram of FFT spectrum

Adaptable Mechanism for Human Characteristics of EMG signal

Discrimination of Motion Patterns

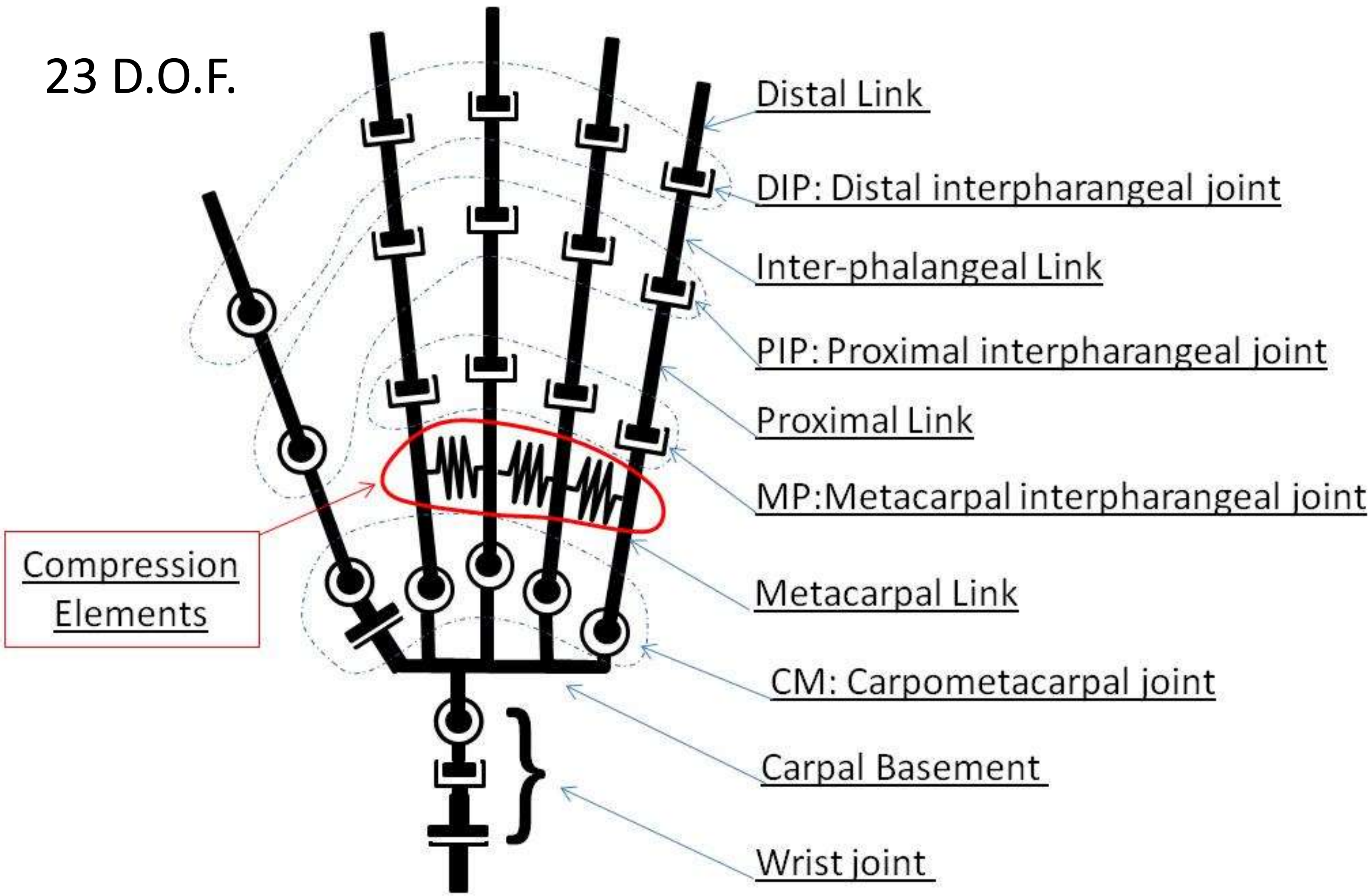


Artificial Neural Net
＋Minimum Entropy
Data Collection

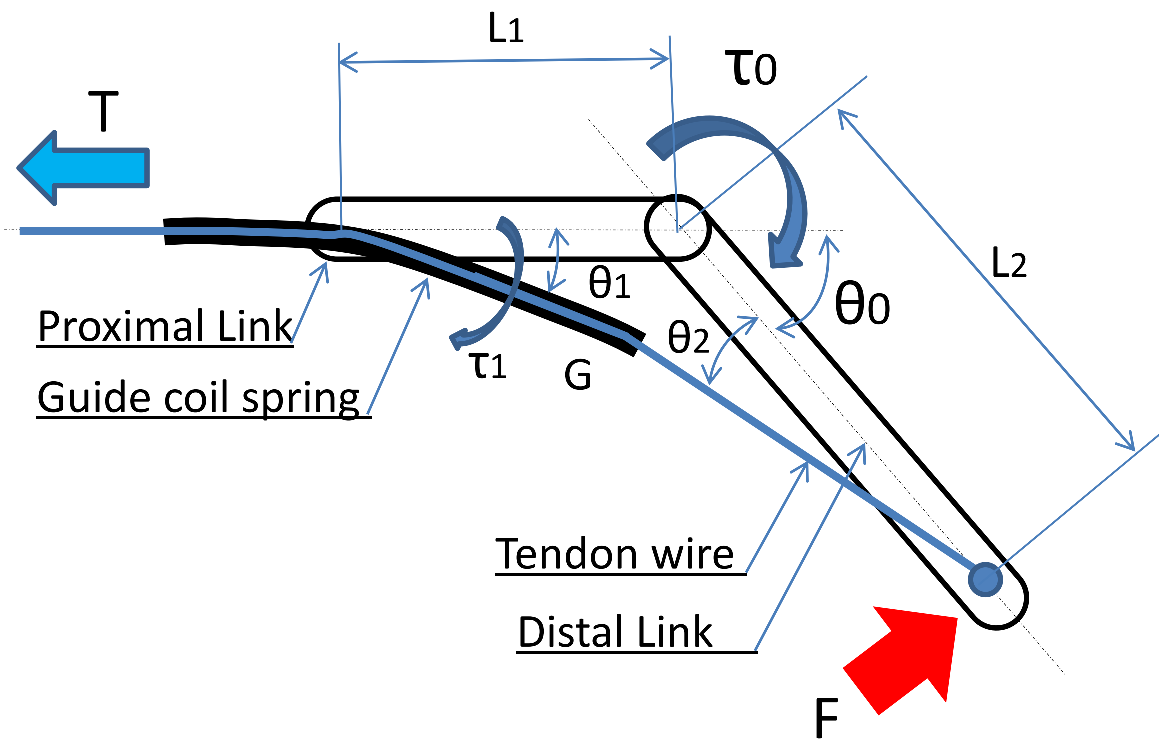
3ch EMG analysis classified 15 intentions of motions

Link Mechanism of Robot Hand

23 D.O.F.



Dynamics of Wire Driven Mechanism for Finger Joint



T : Wire Tension

F : Counter force on the tip of Distal Link

G : Elastic Flexural modulus of the guide coil spring

τ_0: Driving torque of Links

$\tau_0 = F\ L_2$

$= T\ L_2 \sin\theta_2$

τ_1 : Driving torque of the guide coil spring

$\tau_1 = 2\ L_1\ T \sin\{(\theta_0\text{-}\theta_1\text{-}\theta_2)/2\}$

$= G \sin\theta_1$

L1: Length of Proximal Link

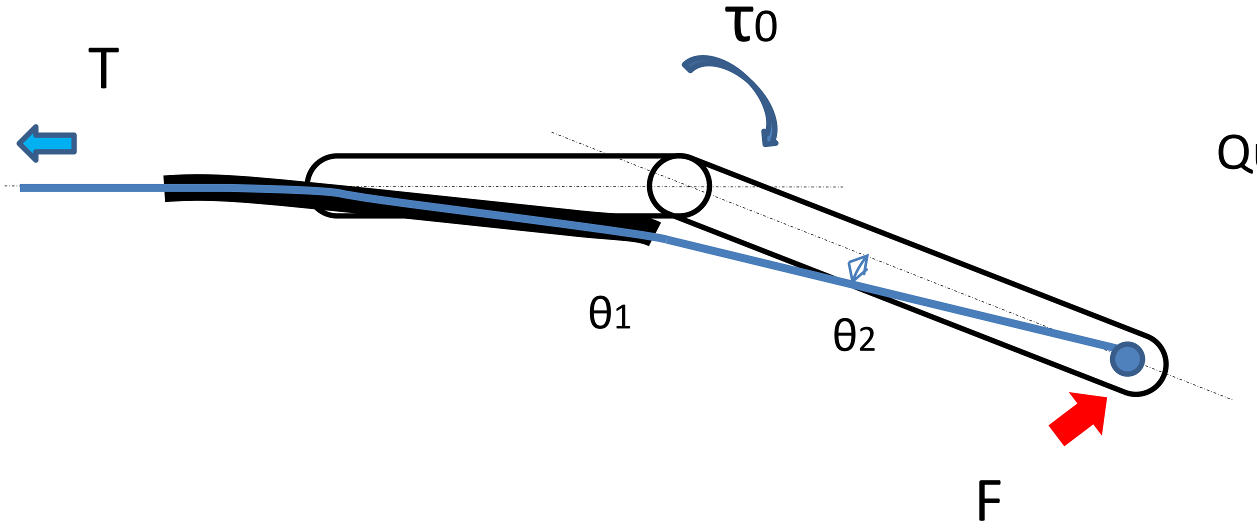
L2: Length of Distal Link

θ_0 : Angle of Links

θ_1 : Angle of Distal link and tendon wire

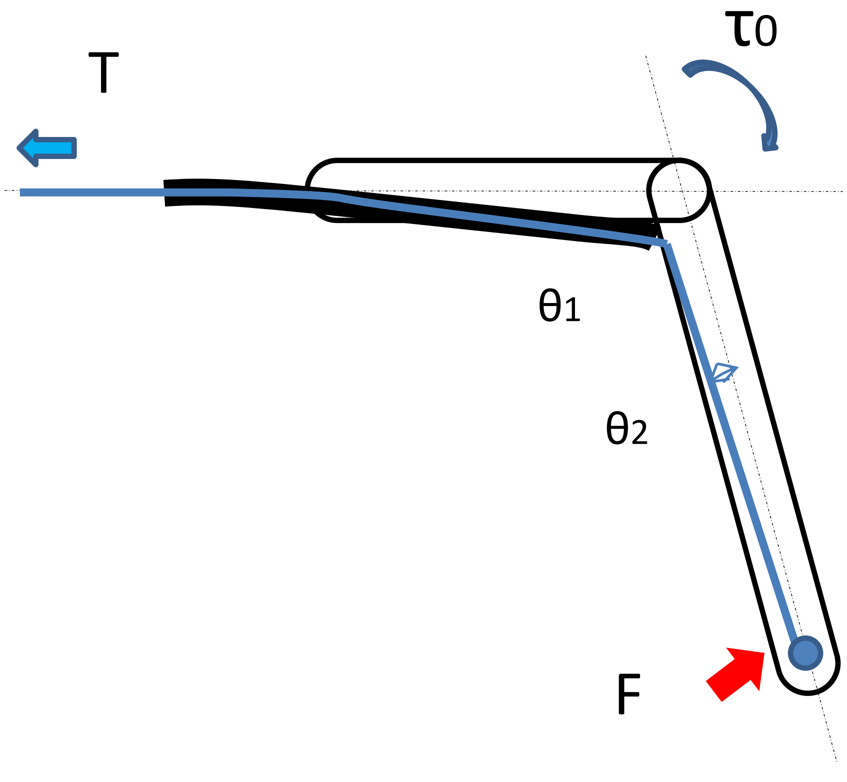
θ_2 : Angle of Proximal link and guide coil spring

Dynamics of Wire Driven Mechanism for Finger Joint



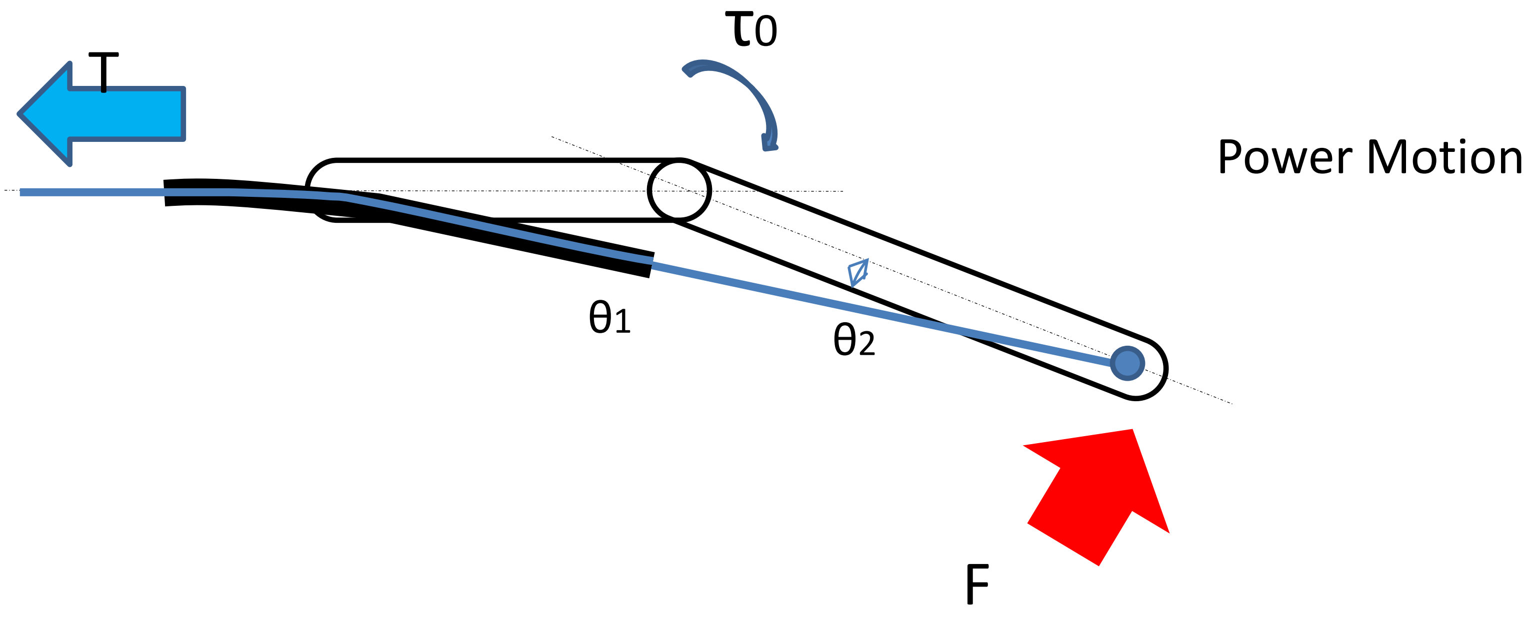
Quick Motion

Dynamics of Wire Driven Mechanism for Finger Joint

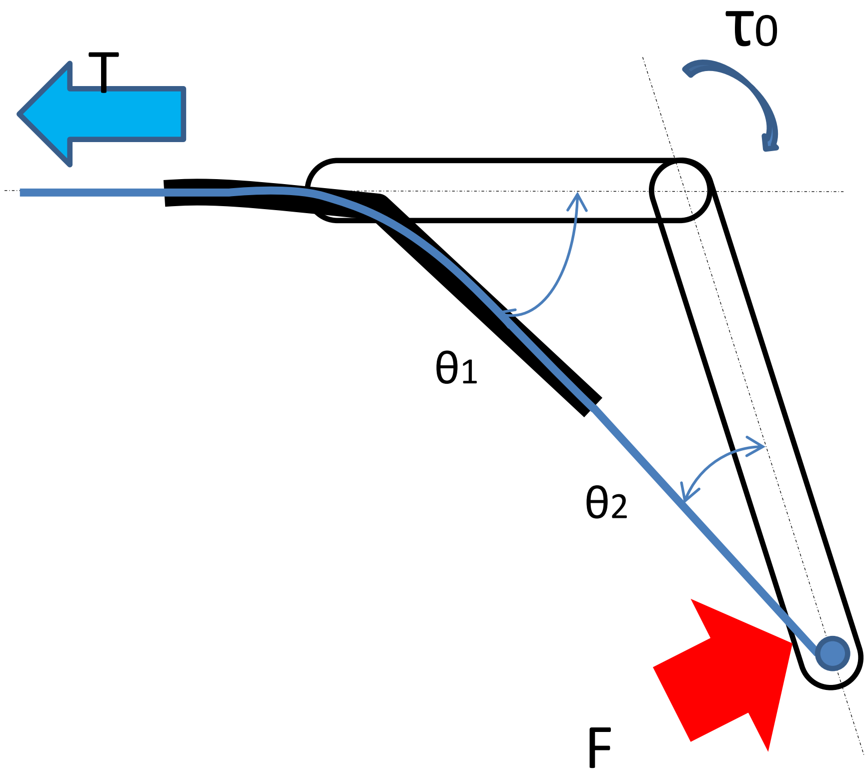


Quick Motion

Dynamics of Wire Driven Mechanism for Finger Joint

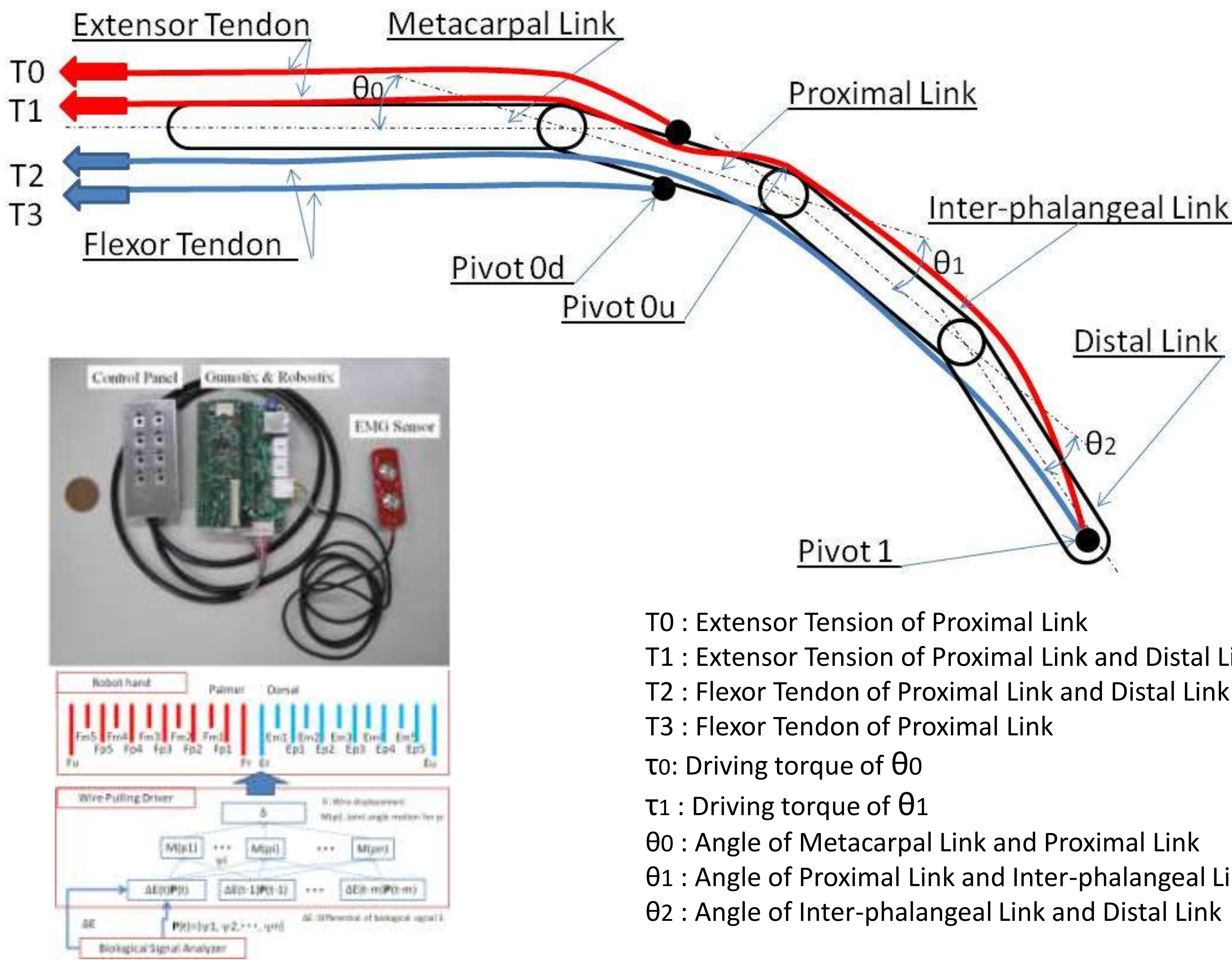


Dynamics of Wire Driven Mechanism for Finger Joint



Power Motion

Interference Wire Driven Mechanism and Control



T0 : Extensor Tension of Proximal Link

T1 : Extensor Tension of Proximal Link and Distal Link

T2 : Flexor Tendon of Proximal Link and Distal Link

T3 : Flexor Tendon of Proximal Link

τ_0: Driving torque of θ_0

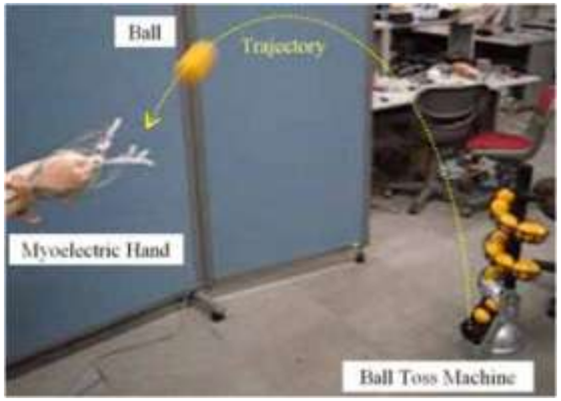
τ_1 : Driving torque of θ_1

θ_0 : Angle of Metacarpal Link and Proximal Link

θ_1 : Angle of Proximal Link and Inter-phalangeal Link

θ_2 : Angle of Inter-phalangeal Link and Distal Link

Demo System



Catch ball

Prototype by Tatsuhiro Nakamura in 2008

ADL Test for Prosthetic Hand

Conventional Studies

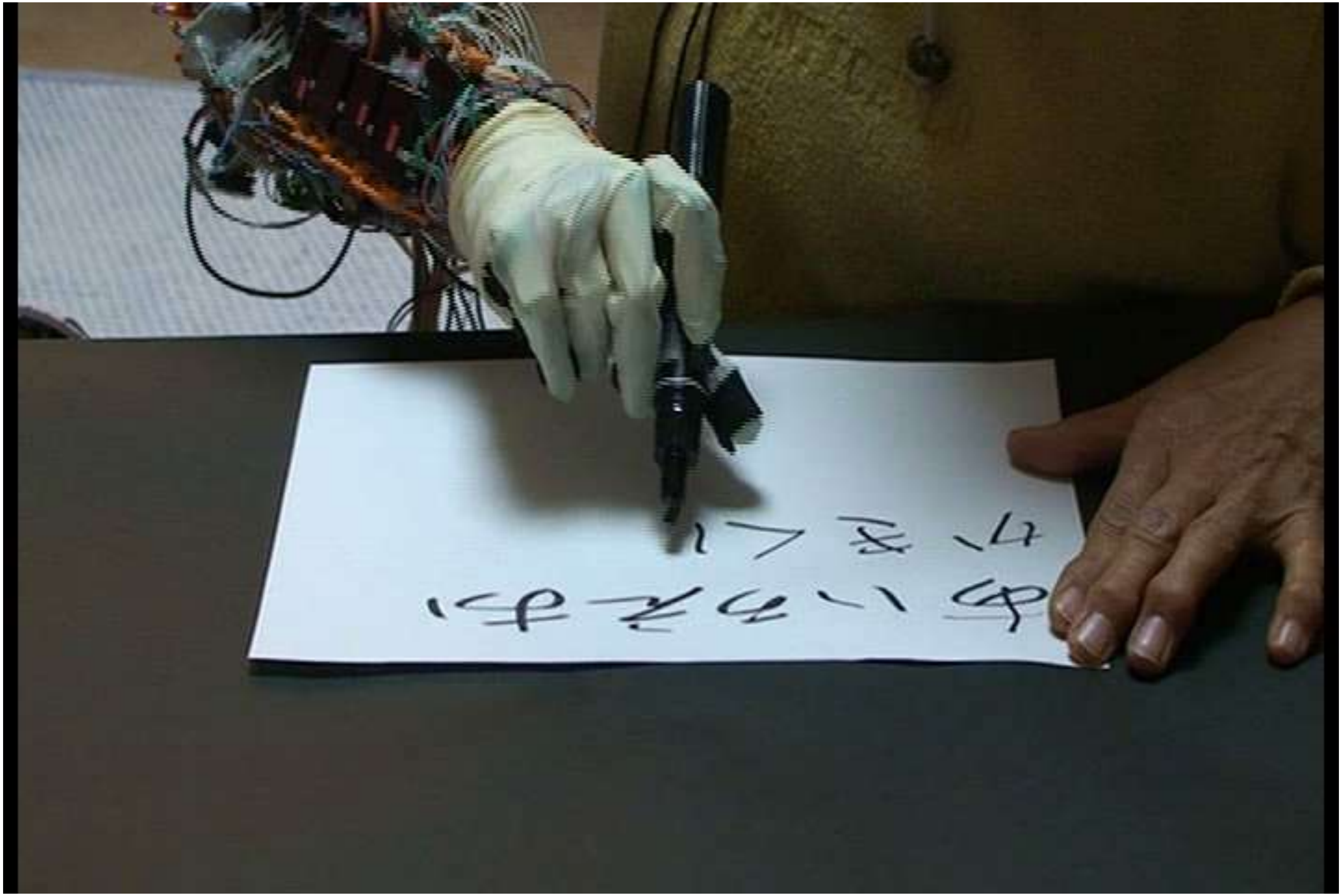
	EMG Discrimination of Motions	EMG Channels	DOF	Weight	Grasping Force
UEC(Tokyo Univ.)	Hand 14	3	13	1200g(Hand + Motor + Controller + Socket)	55N
Hiroshima Univ.	Hand 8	7	1	270g(Hand Only)	1.8N
Duke Univ.	Upper Arm 6	ECoG	3	?	?
Cicago Riha	Upper Arm 6	6?	6	?	?
Uta Univ	?	?	16	Heavy	?
Dean Kaman	No	No	14	3600g	?
Canada + South Sampton(UK)	Hand 4	2+(FSR)	6	400g(Hand Only)	9.1N
Ottobock	Hand 2or4	2	1or2	540g(Hand Only)	160N
Genova	Hand 5	2or3	16	1800g(Hand + Motor + Controller + Socket)	70N
England					
i-LIMB	?	2 (FSR)	6	small508 gmedium 518 g	8 kg~9.5kg

Under developing of Prosthetic hand
ECoG based BMI control for upper arm

Robot manipulator, rather than prosthetic hand
JoyStick control. Grasping power is likely to have a cup.

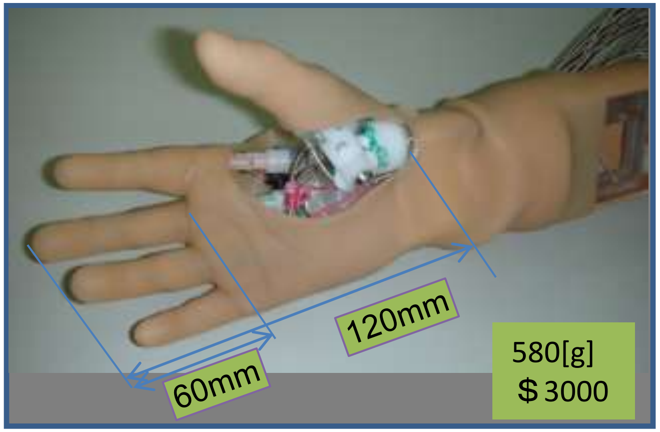
Hand grasping and thumb rotation control based on discrimination by depending on EMG threshold with time interval for mode change control

Need more Precise Control



Application for Child

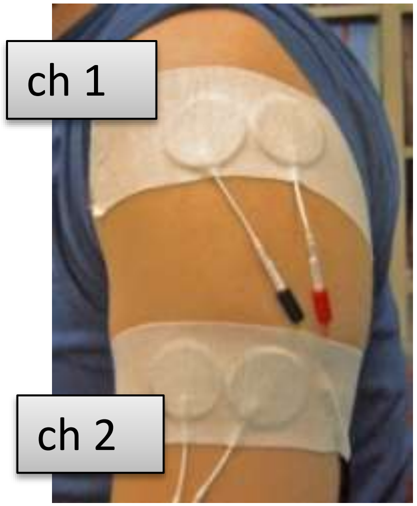
Congenital limbs deficient child (7 years old)



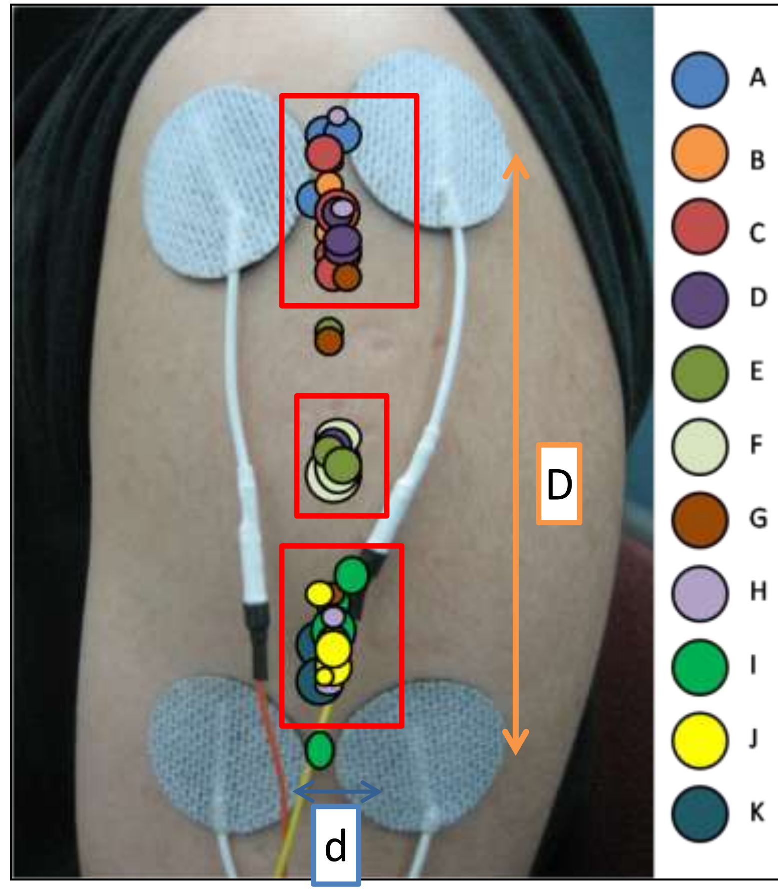
Biofeedback using Phantom Sensation

Tactile sensor

Electrodes



Phantom Sensation



D = 100mm d = 5mm

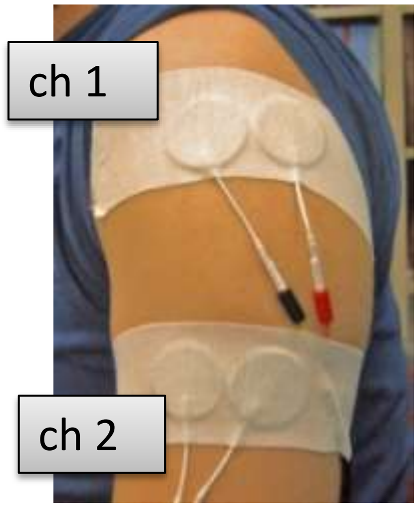
Programmable
Carrier 1～8[kHz]
Burst 1～300[Hz]
Duty 1～99%
Strength ～±100[v]

Functional Electric Stimulator

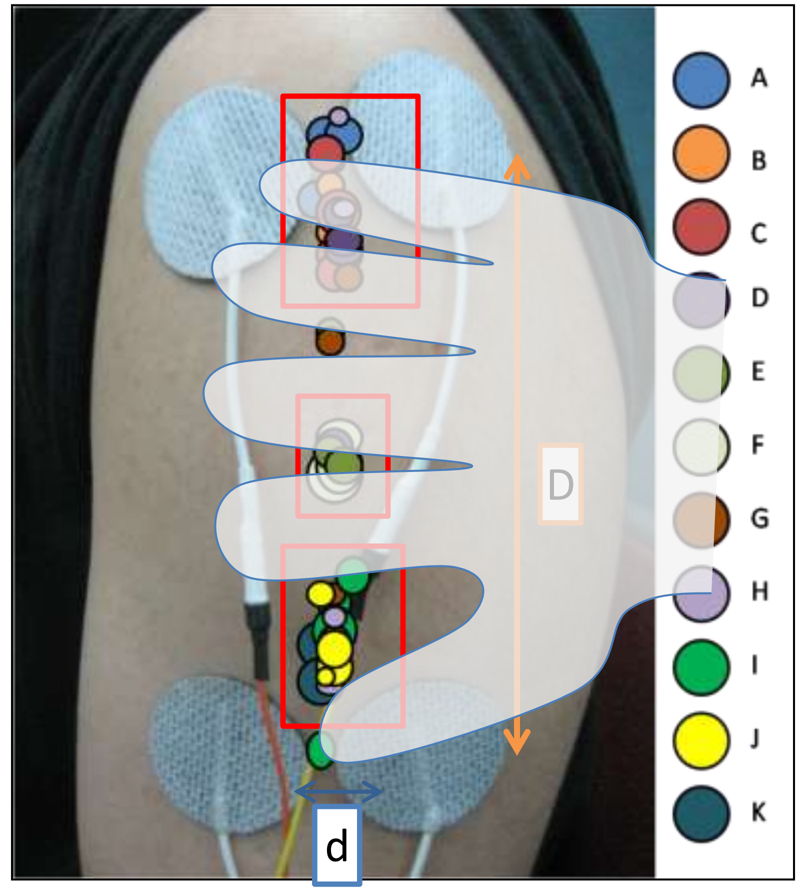
Biofeedback using Phantom Sensation

Tactile sensor

Electrodes



Phantom Sensation



D = 100mm d = 5mm

Programmable
Carrier 1〜8[kHz]
Burst 1〜300[Hz]
Duty 1〜99%
Strength 〜±100[v]

Functional Electric Stimulator

f-MRI Analysis of Adaptation

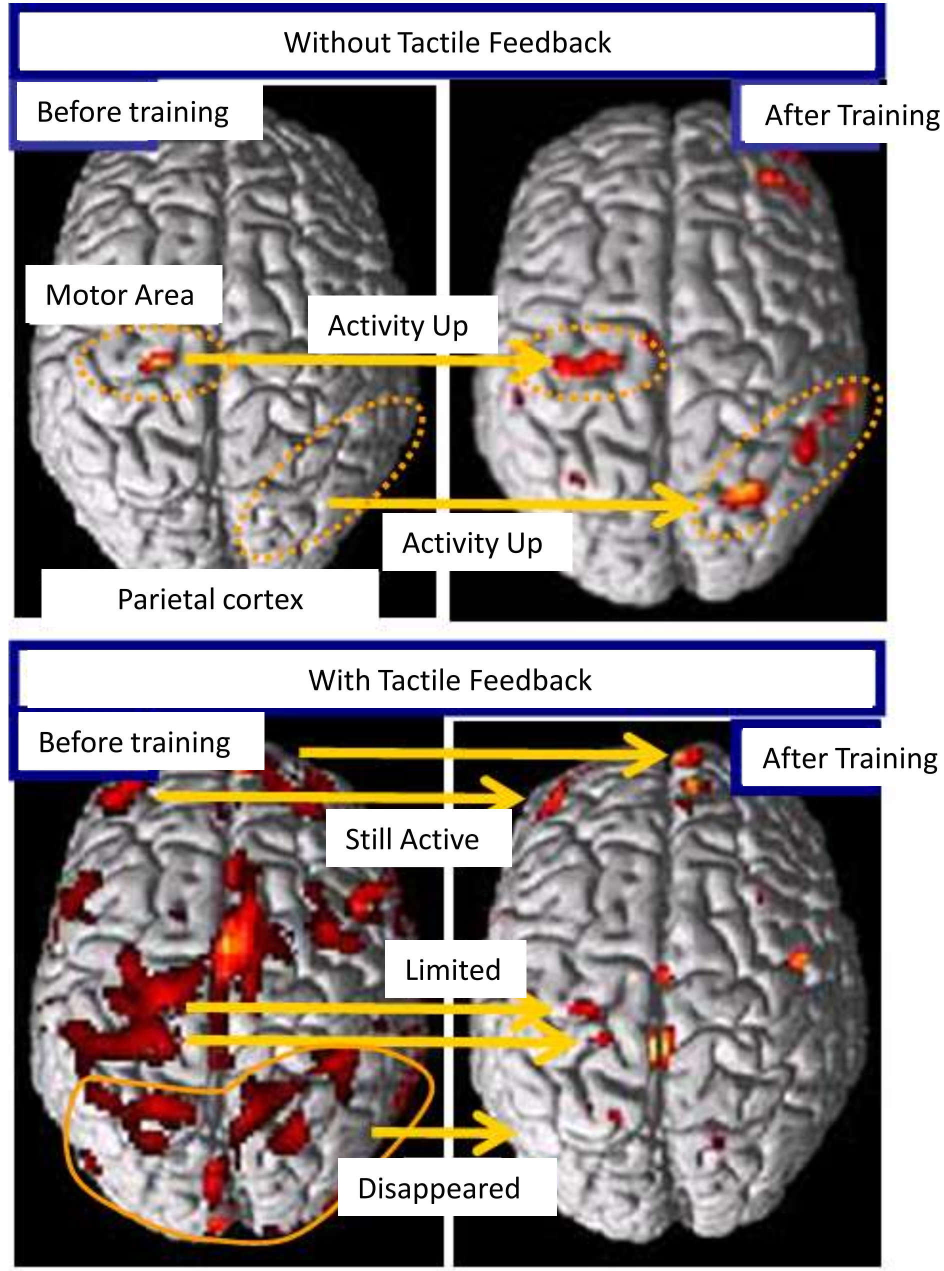
Sensory motor coordination is necessary for confidential grasping.
(Tactile Sensing is important.)

Adaptation vs Habituation

（Effect on the Coexistence of Man and Machine）

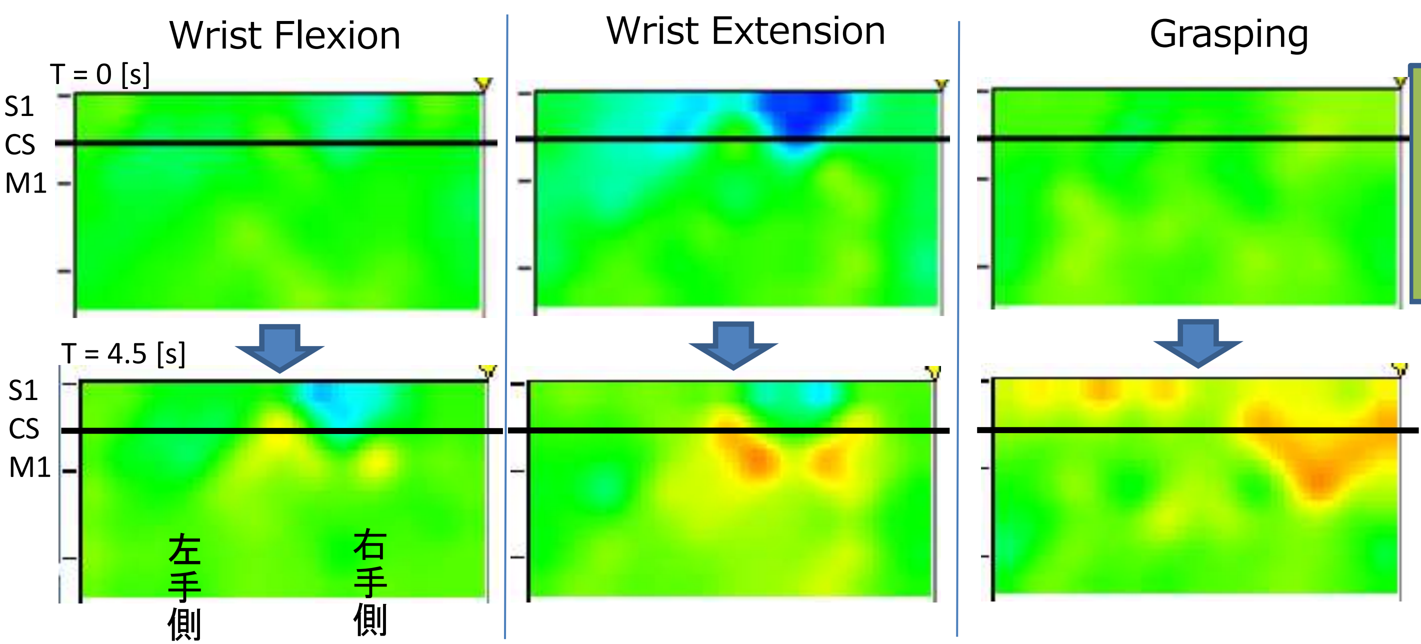
Input type BMI

(We can see how much intelligence do we need to manipulate prosthetic hand)

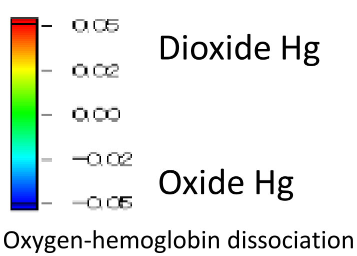


Application of f-NIRS

SIMADU OMM-3000 by Ryu Kato

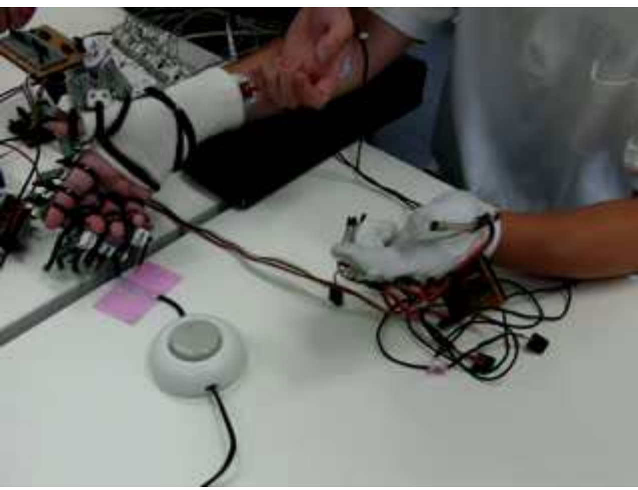
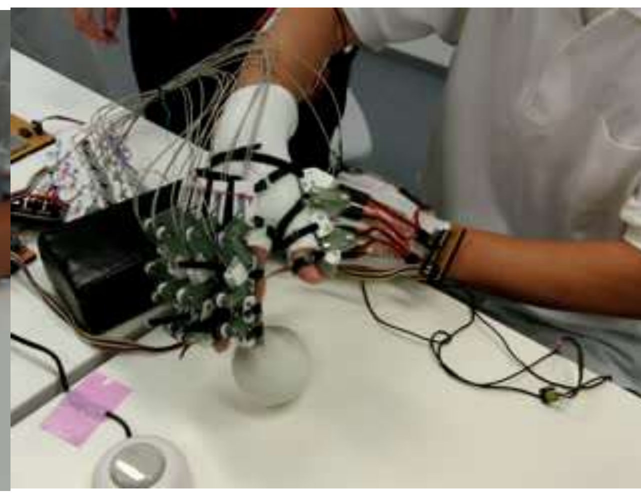


S1: Sensor Area
CS: Central Sulcus
M1: Motor Area



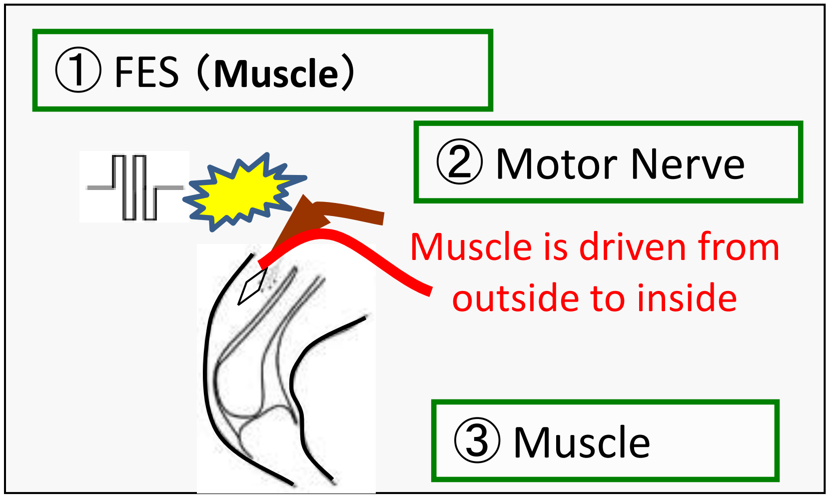
Power Assist Device for the Stroke Patient

（with Fukui Univ.）

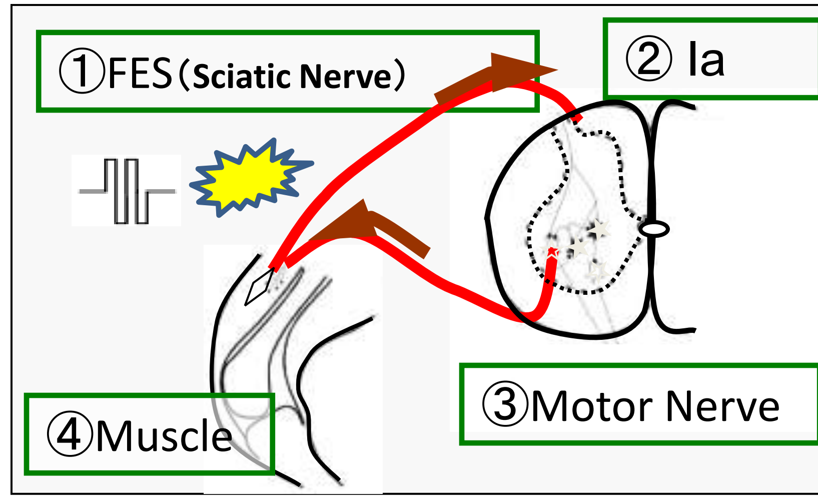

Principle of Walking Assist by using FES

Direct Stimulation on Muscle



Unnatural Recruitment

Reflex Stimulation through Spine



Natural Recruitment

Results of Reflex Walking Assist for Lower Lim Paralysis

Fast Walking	Slow Walking
25m/33s = 0.76 m/s	25 m/87s = 0.28 m/s

37 years old
Spinal L5, S1 injury
When she was 10 years old

FES for Acute Hemiplegic Stroke patients

Case 1, cerebral infarction, BRS Ⅲ (day 8)

Day 10, before FES

Walk10[m] :
97.7[s]
61[step]

Day 10, after FES

Walk10[m] :
48.6[s]
46[step]

FES for Convalescent Hemiplegic stroke patients

Case 2, cerebral infarction, BRS Ⅲ (day 36)

Normal Rehabilitation

Velocity：54s/10m

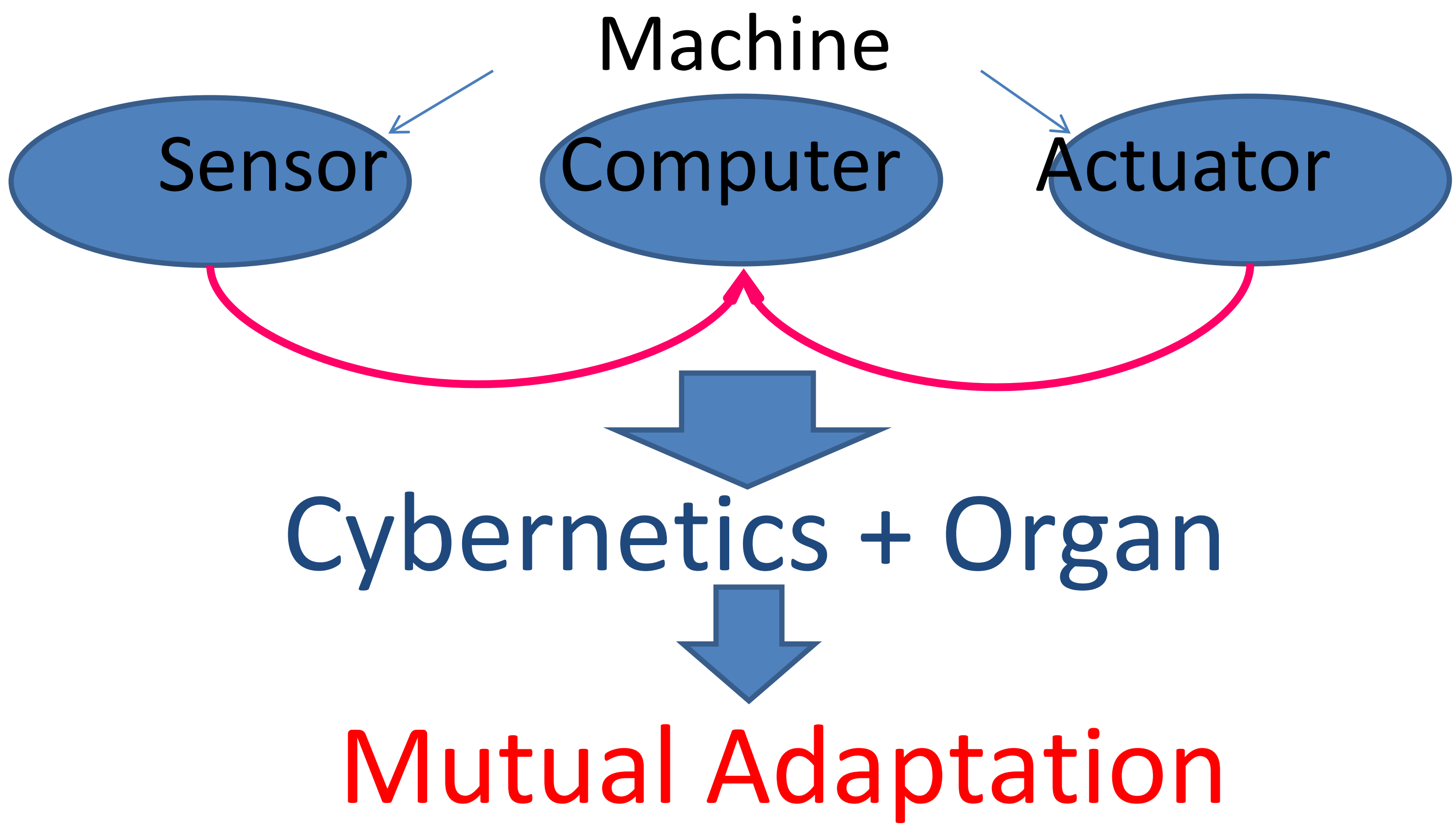
FES training

FES rehabilitation after 1 week

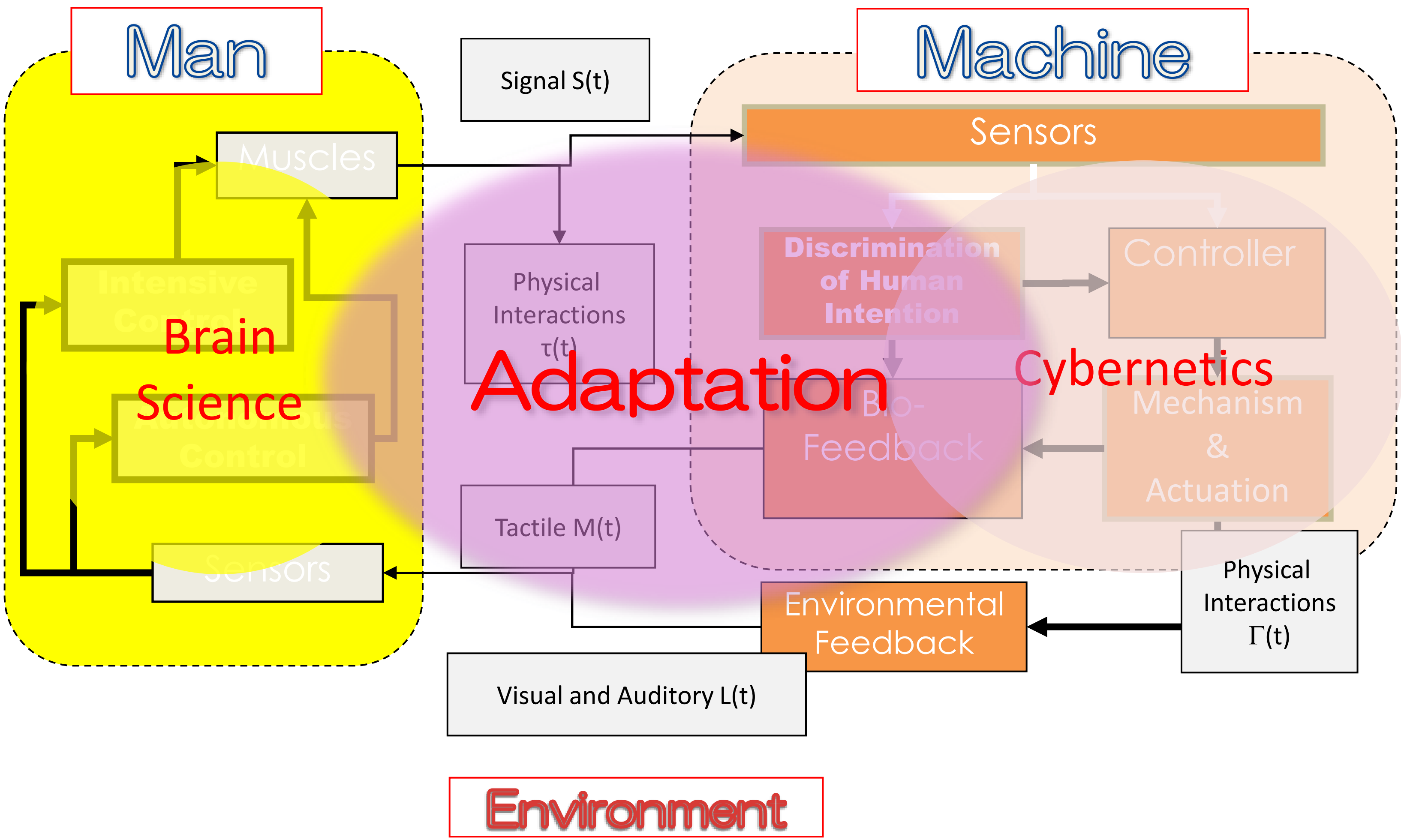
Velocity：22s/10m

Cybernetics

Cybernetics was defined by Norbert Wiener
1948, *Cybernetics: Or Control and Communication in the Animal and the Machine.* Paris, France: Librairie Hermann & Cie, and Cambridge, MA: MIT Press.Cambridge, MA: MIT Press



Adaptable Mechanism for Human Intention of Motion



Conclusions

- New trend of brain science for neuro rehabilitation is started, engineers need to produce the robot which has intelligence to adapt human intention
- Machine function is growing from the traditional cybernetics to the integration of actuator, sensor, computer and human body by using biofeedback.
- Adaptable mechanism for biological signal will connect to human and Machine through biofeedback.
- Engineering application of barrier free technology is useful for physically, socially and mentally.