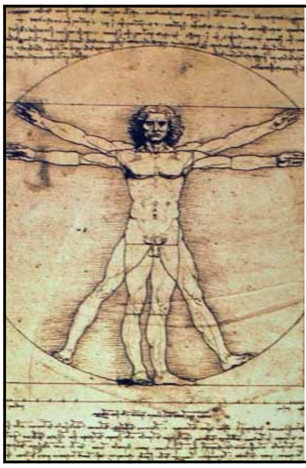


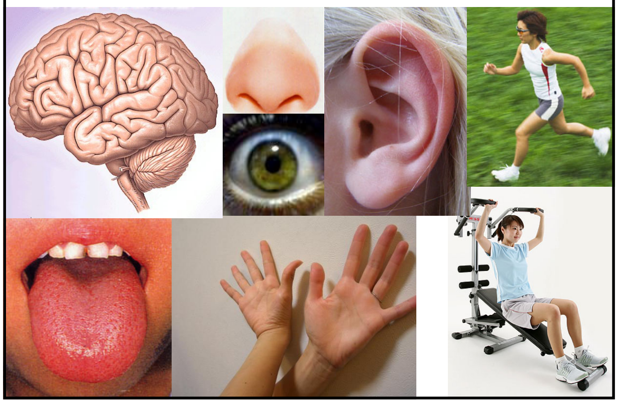
Interactive System
インタラクティブシステム特論(1)

Hiroyuki Kajimoto
kajimoto@hc.uec.ac.jp
Twitter ID kajimoto

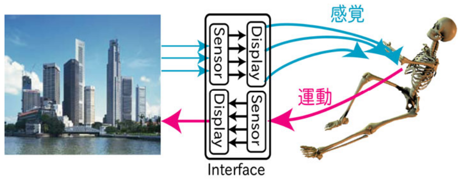
言語 / Language

●講義は日本語、資料は英語。
✓専門用語は併記
●Lecture in Japanese, handouts in English.

Self Introduction: Research field = Human Interface



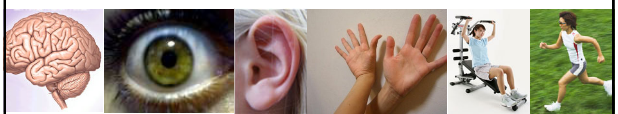
Necessary Knowledge for the research



- ヒトの特性／Human perception
- 最新技術(センサ)／Today's sensing technology
- 最新技術(ディスプレイ)／Today's display technology

This Lecture aims to roughly sketch
"optimal design method based on human perception"

Outline of the lecture



1. 人間計測手法／Measuring Human
2. 視覚／Human Vision System
3. 視覚センシング／Visual Sensing
4. 視覚ディスプレイ／Visual Display
5. 聴覚、聴覚インタフェース／Auditory Interface
6. 触覚、触覚インタフェース基礎／Tactile Interface Basics
7. 触覚、触覚インタフェース応用／Tactile Interface Applications
8. 力覚、力覚インタフェース／Haptic Interface
9. 移動感覚インタフェース／Locomotion Interface

Schedule

- 4/5 • 講義(lecture)
- 4/12 • 講義(lecture)
- 4/19 • 講義(lecture)
- 4/26 • 講義(lecture)
- 5/10 • 休講
- 5/17 • 講義(lecture)(休講の可能性あり)
- 5/24 • 講義(lecture)
- 5/31 • 講義(lecture)
- 6/7 • 休講 (6/1 オープンラボ研究室見学(任意))
- 6/14 • 講義(lecture)
- 6/21 • 講義(lecture)
- 6/28 • 講義(lecture)
- 7/5 • プレゼンテーション(presentation)1
- 7/12 • 休講 (6/15 オープンラボ研究室見学(任意))
- 7/19 • プレゼンテーション(presentation)2
- 7/26 • 休講

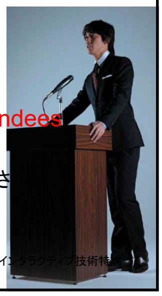
小テスト/ Mini Test

- 講義の目的の一つが「基礎知識を得ること」なので、各回小テストを行います。
- **Google Formに入力する形で回答。: https://goo.gl/forms/85xfExX2mLheNncR2**
- **回答テキストをフォームにコピペして提出してください**
- **締め切り：次回の授業開始まで**

- E-mail report based mini tests are done every time.
- **Upload to https://goo.gl/forms/85xfExX2mLheNncR2**
- **Deadline: Before the beginning of the next lecture**

発表/ Presentation
Your PowerPoint Presentation is required.

- 英語の論文を一つ読み，その内容を発表.（読む候補はこちらで用意します）
  Read a paper and do presentation.
  (candidate papers will be announced)
  - 今のところ発表8分，質疑4分.
- 発表は全員で評価
  The presentation is evaluated by all attendees
  - 1. 発表内容に対する理解度
  - 2. 発表用資料（パワーポイント）の分かりやすさ
  - 3. 発表の分かりやすさ
  - 4. 質問に対する受け答え
  - 5. 総合的な印象



評価/ Evaluation

- 点数＝出席(40%)+小テスト(5%×8)+発表(20%)
- ただし発表をすることが評価の前提条件
- 電通大以外の場合（スーパー連携大学院）=Attendance (60%) + Mini Test (5% x 8)

- Evaluation=Attendance (40%) + Mini Test (5% x 8) + Presentation (20%)
- Presentation is required

Handouts on the web

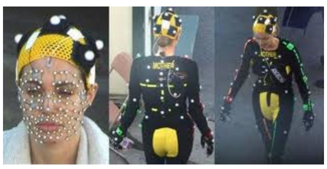
http://kaji-lab.jp/ja/index.php?people/kaji/interactive

–現在は2018年版がおかれています。徐々に変えていきます。
–Temporary, 2018 Japanese version. Will be replaced progressively.

–**こちらのpdfには動画のリンク先(Youtube等)が埋め込まれているので、紙資料よりも便利。次回から紙資料は配布せず、講義の1時間前までにアップロードします。必要なら事前にダウンロードしてください**

–**From next time, lecture handouts will be online 1 hour before the lecture. Print it if necessary.**

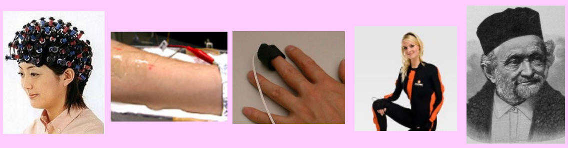
Today's Topic:
人間計測手法／Measuring Human



ヒトの計測：
- •インタラクティブシステムの**構成要素**
- •インタラクティブシステムを**評価するため**にも必須

Measurement of human action/reaction
- •To be used **as parts of** the interactive system
- •To **evaluate** the system

人間計測手法／Measuring Human

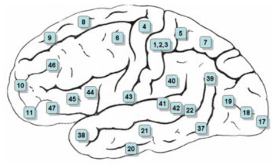


意志から行動までの「どの経路を測るか」で5つの段階
Five layers, *from* our initial will *to* our perception.

●脳活動計測／Measure brain activity.
●神経・筋活動計測／Measure nerve activity.
●自律神経系計測／ Measure autonomic nerve related phenomenon.
●運動計測／Measure motion.
●心理物理実験／Ask the user (psychophysics)

History of Brain Function Observation(1)

- Theory of localization of brain function：
  - 1909：ブロードマンBroadmann made “map” of the brain by visual observation. (microscope)
  - WWI: Better guns = many patients with “partial” brain damage



Broadmann’s map：
52 regions of the cortex defined based on organization of cells.

History of Brain Function Observation(2)

- 1933：ペンフィールドPenfield
  Before Brain surgery for epilepsy, he stimulated brain directly by electrical needle. while the patients were awake.
  Result: Many functional region were found, including memory, sensory, and action.
- 1940: ロボトミーLobotomy
  Cut frontal lobe of the brain for mental disease, especially for violent patients.
  Result: Became calm, but also became like “robot”⇒Frontal lobe seems to be related to “emotion”

- 1960：X-ray CT gave clear view of the brain, without surgery.

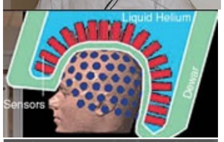
脳機能計測／Measurement of Brain Function

- Not the measurement of brain, but brain function. Must be done during some work. (see, touch, think)
- State-of-the-art measurement technologies are used.
  - Measure “Electrical Activity”
    - 脳波／EEG(brain wave), 1929～
    - 脳磁／MEG, 1972～
  - Measure “Blood Flow”
    - fMRI(functional MRI), 1973～
    - PET, 1965～
    - NIRS, 1994～
  - Active method
    - Use magnetic stimulator

EEG (Brain Wave)

- EEG: Electroencephalogram
- 21～60 electrodes on the scull skin.
- Good points
  - Cheap!
  - Very fast (ms)
- Bad points
  - Low spatial resolution.
  - Skin-electrode conductance is unstable.
  - Can measure “surface”, but cannot measure “deep region”
- Still used in many interactive systems

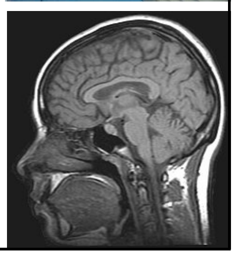
MEG



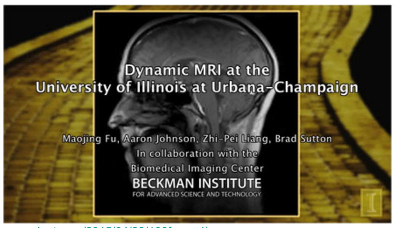
- MEG:Magnetoencephalography
- Similar to EEG, but measure “magnetic field” induced by electrical current.
- **Very, very tiny magnetic field** (about 1/10^8 of the earth’s magnetic field)
- Superconducting technology is used. (SQUID:Superconducting Quantum Interference Device)
- Good points
  - Very Fast (similar to EEG)
  - Can measure deep region. (magnetic field penetrates everything) .
- Bad points
  - Surface sensors = 2D
  - Current sources = 3D mathematically very difficult to solve (almost impossible)

MRI(核磁気共鳴画像法)

- MRI:Magnetic Resonance Imaging
  - Very strong magnetic field make protons to “emit” electromagnetic waves.
  - By measuring this waves, can obtain 3D structures.
- Good points(compaired to X-ray CT)
  - No X-ray (=good for body)
  - Bone is not an obstacle
  - 3D data are obtained (X-ray CT:2D)
- Bad points
  - Very strong magnet (3T-): metal cannot be carried on.
  - Takes a few seconds for a single shot (now improving).
- Current standard for “brain imaging”



100fps MRI



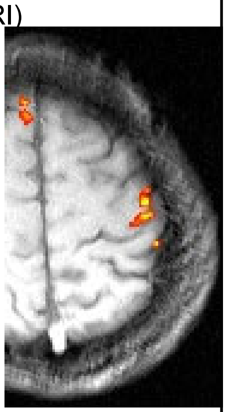
- http://japanese.engadget.com/2015/04/23/100fps-mri/
- イリノイ大学アーバナ・シャンペーン校のベックマン先端科学技術研究所が、秒間100コマの撮影が可能なMRI技術を開発しました。
- ベックマン研究所が開発した技術を大雑把に説明すれば、単純にフレームレートを上げると発生してしまう S/N 比の低下を回避するため、フレーム間を補完する特殊な取得方法を開発、利用しているとのこと。これにより撮像時間は従来のおよそ10倍、約100fps にまで高められています。
- 論文は Magnetic Resonance in Medicine誌 "High-resolution dynamic speech imaging with joint low-rank and sparsity constraints" (Maojing Fu, Bo Zhao, Christopher Carignan, Ryan K. Shosted, Jamie L. Perry, David P. Kuehn, Zhi-Pei Liang, and Bradley P. Sutton)

Exploding MRI

超伝導→突然の停電→常伝導→流れていた大電流に電気抵抗がかかり超発熱→冷やしていた液体窒素が瞬時に蒸発→爆発

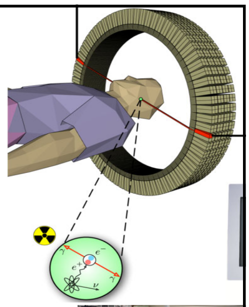
http://www.youtube.com/watch?v=uxlOn5fCoAw&feature=share

fMRI =functional MRI(機能的MRI)

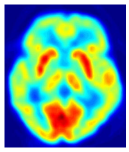


- We must measure brain "activity", not shape.
  - By using MRI, measure "blood flow", by measuring two hemoglobins' ratio.
  - Hemoglobin: container of oxygion.
    - Red = many oxygen.
    - Blue = few oxygen.
- Good point
  - Location is very accurately determined.
- Bad point
  - Requires a few minutes for single shot.
- Current standard for brain functional imaging.

PET(ポジトロン断層法)

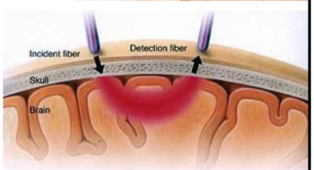


- PET = Positoron Emission Tomography
  - Inject Radioactive ingredient as a "tracer" (O15)
  - The "tracer" collapses, and generate two "γ waves" to the opposite direction.
  - The detector detects the phenomenon.
  - Position is determined by timing measurement.
  - Blood flow can be measured.
- Good point
  - A little faster than fMRI(a few second)
- Bad points
  - radioactive ingredient is necessary.
  - Lower resolution than MRI



NIRS(近赤外分光法)

- NIRS=Near InfraRed Spectroscopy
  - Scull bone is transparent to InfraRed light.
  - Put InfraRed light, and obtain brain surface image.
  - Hemoglobin: container of oxygion.
    - Red = many oxygen.
    - Blue = few oxygen.
- Good points
  - No invasive. Easy to use.
- Bad points
  - Low spatial resolution
  - A few seconds are necessary



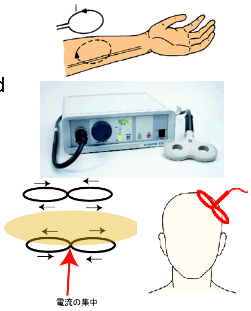
Summary of Brain Functional Imaging

手法 Method	観察対象 Observe	空間解像度 Spatial Resolution	時間解像度 Temporal Resolution
EEG	Electric	Low	High
MEG	Electric	Low	High
fMRI	Blood	High	Low
PET	Blood	Mid	Mid
NIRS	Blood	Mid	Mid

（発展トピック）磁気パルス刺激による能動的観察
Active Measurement by Stimulation

Recall Penfield’s method.

- Magnetic Pulse from outside
  - Small “eddy current” is induced inside the brain.
  - The current stimulates nerves
  - Region can be localized to about 1cm^3

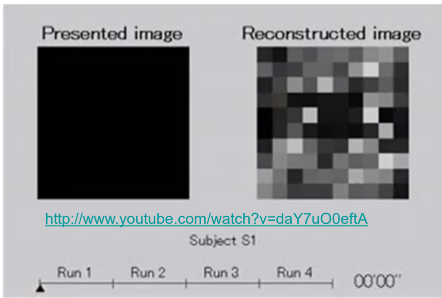


Brain Machine Interface (BMI)

- Growing Field
- Mainly used EEG and NIRS (Fast response is necessary)
- For welfare: for ALS(Amyotrophic Lateral Sclerosis)
  - a progressive, fatal, neuro disease caused by the degeneration of motor neurons.
- Current status: Yes/No, or a few commands.


Video ホンダのBMI

見たものを知る



http://www.youtube.com/watch?v=daY7uO0eftA

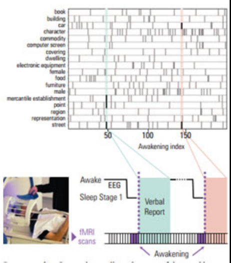
脳活動パターンから見ている図形を画像として再構成する. 視野 を複数の解像度で小領域に分割し、それぞれの領域のコントラスト値をfMRIで計測される脳活動パターンから予測。その予測値を組み合わせることで画像全体の再構成を行う。この手法を用いることにより、脳活動パターンの学習に用いていない幾何学図形やアルファベットの形が再構成できる

Miyawaki et al., “Visual image reconstruction from human brain activity using a combination of multi-scale local image decoders”

http://www.cns.atr.jp/dni/research/visual-image-reconstruction/

夢を知る

脳波計(EEG)を装着した3人の被験者にfMRI装置の中で眠ってもらい、睡眠中の脳活動の計測を行い、脳波をモニタリングしながら睡眠状態の判定をリアルタイムに行い、夢見と強い関連があると知られている睡眠脳波のパターンが生じたタイミングで被験者を起こし、直前まで見ていた夢の内容を報告してもらった後、再び被験者に眠ってもらい、夢を見てもらい報告してもらう(夢報告)ということを各被験者ごとに約200回実施。
夢報告に現れる物体や風景を表す名詞などを抽出し、言語データベースを用いて解析することで、非定形な夢報告文を主要な本やクルマなど約20の物体カテゴリの有無を表現するベクトルに変換したほか、主要な物体カテゴリに対応する画像をWeb上の画像データベースから収集し、それらの画像を見た時の大脳視覚野の脳活動を使って、物体情報を解読するパターン認識アルゴリズム(デコーダ)を構築。



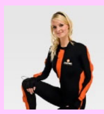
http://news.livedoor.com/article/detail/7566434/

T. Horikawa, M. Tamaki, Y. Miyawaki, Y. Kamitani, Neural Decoding of Visual Imagery During Sleep, Science, April, 2013.

http://www.sciencemag.org/content/early/2013/04/03/science.1234330.abstract

人間計測手法／Measuring Human




意志から行動までの「どの経路を測るか」で5つの段階
Five layers, *from* our initial will *to* our perception.

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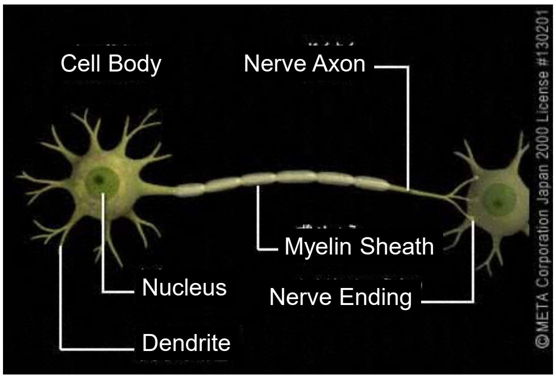
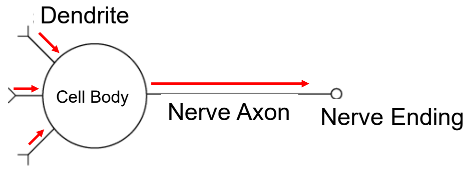
Nerve: Basics

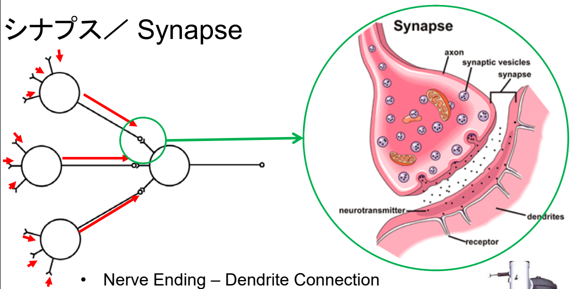


Nerve structure



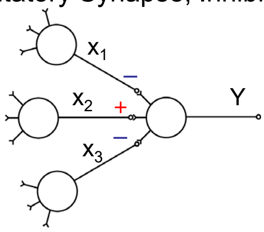
- 樹状突起／ Dendrite: Input Connector
- 細胞体／ Cell Body: Calculator (Summation)
- 軸索／Axon: Output Cable
- 神経終末／ Nerve Ending: Output Connector

シナプス／ Synapse



- Nerve Ending – Dendrite Connection
- 20nm "Synaptic cleft"
  - First Discovery: Electron Microscope
- 1st nerve: Electrical Pulse ⇒Chemical Output
  - Capsules break, and neurotransimitter showers.
- 2nd nerve: ⇒Chemical Input⇒Electrical Current
- "One way" connection
- 0.1-0.2ms necessary

興奮性シナプス・抑制性シナプス Excitatory Synapse, Inhibitory Synapse

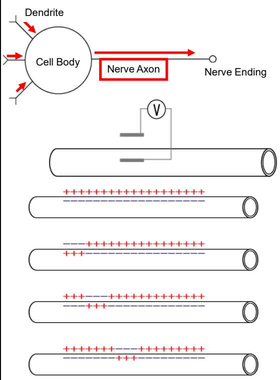


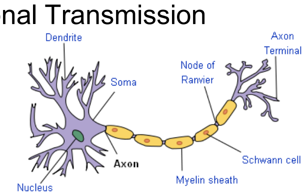
$Y=F(X_1-X_2-X_3)$

F(X)=1 when X≧Threshold
=0 when X < Threshold

- Cell Body: Take Summation Σ
- Excitatory Synapse: Plus(+) input
- Inhibotory Synapse: Minus(-) input
- Synaptic weight change = Learning and Memory

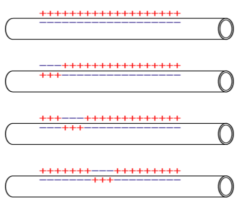
軸索上の電位伝搬／Axonal Transmission

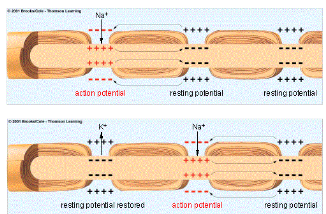




- Chemical "ion" is exchanged via membrane.
- Ion exchange propagates.
- Voltage Difference ~70mV

軸索のタイプ／Axon types



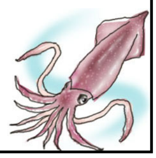


- Axon length: Reaches to 1m.
- ミエリン髄鞘／Myelin Sheath: Insulator
- Electrical Current is limited to very small "gap" (ランビエ絞輪／Ranvier Node)⇒Very Fast "Skip"
- 有髄神経：Myelinated axon=very fast
- 無髄神経：Unmyelinated axon = very slow

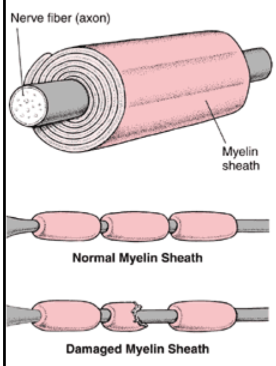
信号伝搬速度／Conduction Velocity

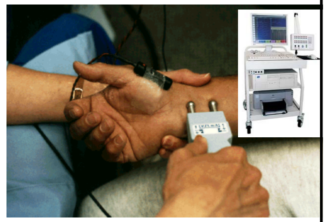
	name	diameter(μm)	velocity(m/s)	role
有髄神経 Myelinated	Aα	15	100	Many muscle nerves
	Aβ	8	50	Many sensory nerves
	Aγ	5	20	Some muscle and sensory nerves
	Aδ	3	15	Fast pain
無髄神経 Unmyelinated	C	0.5	1	Slow pain, heat, cold sensation, etc

- Rule: Thicker = Faster
- Myelinated Axon: Invention of vertebrate animals (animals with back-bone).
- Other animal's strategy: Thicker the better.
  - ex）Squid's gigantic nerve (diameter: 0.5mm)



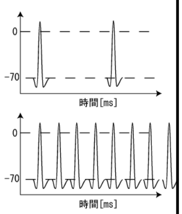
Conduction velocity and diabetic (糖尿病)



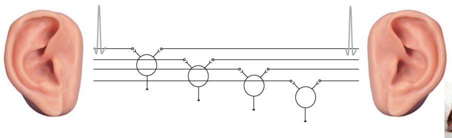


- Diabetic: Quite common disease by taking too much sugar.
- It damages Myelin Sheath so that nerve conduction is inhibited.
- Finally, one cannot sense anything (blind, etc)
- Inspection: measure conduction velocity

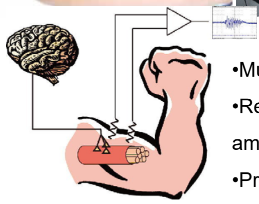
Information Coding by the Nerve



- Repetition Ratio
  - Strong Stimulus⇒High Frequency
  - Single pulse means nothing.
- Timing
  - One nerve is activated when two inputs come simultaneously (at the same time).
  - (ex) Owl's Sound-Source Detection Mechanism



筋電計測
Measurement of muscle fiber activity

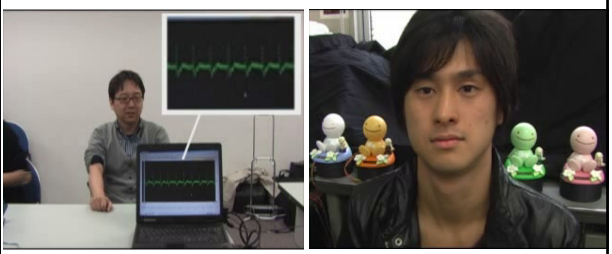


•Muscle Nerve ⇒Muscle Fiber Activity

•Relatively easy with differential amplifier circuit (差動増幅回路).

•Problem: Conductive Gel is required.

(ex) 笑いの増幅
Augmentation of Laugh



●Take initial laugh timing by measuring muscle activity.

●Enhance the laugh by using "empathy effect"

多電極化
Multi-electrodes

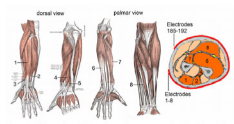


Figure 1. Illustration of the relevant forearm muscles. The dorsal view shows the extensors, the palmar view shows the flexors. The right most picture shows a cross section of the forearm in the middle between the distal and the proximal end. The red line around it indicates the approximate position of the electrode array. The muscles are 1: M. extensor digitorum communis, 2: M. extensor digiti minimi, 3: M. extensor pollicis brevis, 4: M. extensor pollicis longus 5: M. extensor indicis, 6: M. flexor digitorum profundus, 7: M. flexor pollicis longus, 8: M. flexor digitorum superficialis (pictures from Wikimedia Commons)

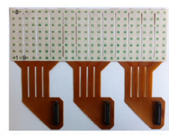


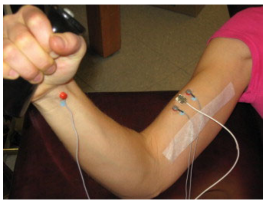
Figure 2. Picture of the electrode array used. The inter-electrode-distance is 10 mm. The electrodes are arranged in a 8x24 grid. Electrode numbering starts at the lower left corner and works columnwise.

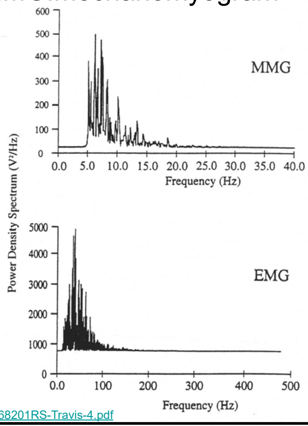
8x24の電極群を前腕に巻きつけ
ジェスチャ学習

Figure 3. Picture of the actual setup used: (1) electrode array, (2) preamplifier, (3) Reference electrode, (4) DRL circuit, (5) data glove (not used), (6) real-time signal visualization, (7) guiding software, (8) amplifier, (9) recording computer

Christoph Amma et al., Advancing Muscle-Computer Interfaces with High-Density Electromyography, CHI2015

（発展トピック）筋音計測MMG:mechanomyogram





•筋繊維の「きしみ」で音が出る現象。
•加速度計やマイクを体表に貼付するだけで非侵襲測定
•皮膚表面状態（汗等）に影響されない
•EMGに比べ低周波
•原理は完全には未解明

http://www.trnres.com/ebook/uploads/travis/T_1279268201RS-Travis-4.pdf

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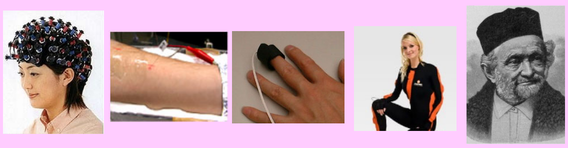
EMPress: Practical Hand Gesture Classification with Wrist-Mounted EMG and Pressure Sensing, CHI2016
Jess McIntosh, Charlie McNeill, Mike Fraser, Frederic Kerber, Markus Löchtefeld, Antonio Krüger

手のジェスチャ認識において，圧力分布と筋電分布を合わせて使うと正答率が上がる

人間計測手法／Measuring Human

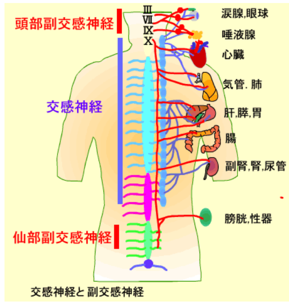


意志から行動までの「どの経路を測るか」で5つの段階
Five layers, *from* our initial will *to* our perception.

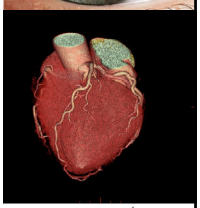
●脳活動計測／Measure brain activity.
●神経・筋活動計測／Measure nerve activity.
●<u>自律神経系計測／ Measure autonomic nerve related phenomenon.</u>
●運動計測／Measure motion.
●心理物理実験／Ask the user (psychophysics)

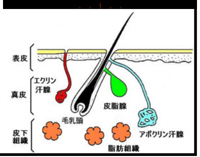
自律神経／Autonomic Nervous System

Nervous system that acts as a body control system.
Composed of Sympathetic nervous system(SNS:交感神経)
and Parasympathetic nervous system(PSNS:副交感神経).



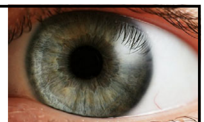
Sympathetic nervous system (SNS:交感神経)

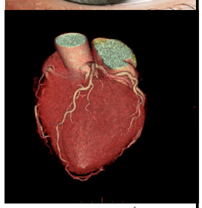


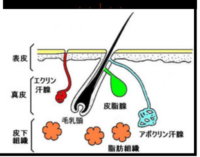


- **Nervous systems for “Fight and Flight”** (闘争と逃走)
- Eye Pupils（瞳孔）→Open
- Heart(心臓) →Blood Pressure & Beat ↑
- Skin(皮膚)
  - Sweat Grand(汗腺)→Sweat(発汗)
  - Hair Elector Muscle (立毛筋)→Contract(収縮)
- Blood Vessel(血管) →Expand 拡張（一部収縮）

Parasympathetic nervous system (PSNS:副交感神経)



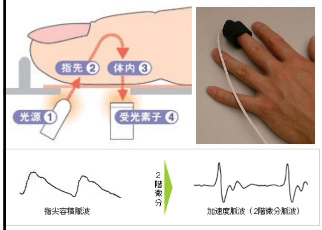




- **Nervous systems for “calming”** (沈静)
- Eye Pupils（瞳孔）→Close
- Heart(心臓) →Blood Pressure & Beat ↓
- Blood Vessel(血管) →Contract 収縮（一部拡張）

情動を測定／Measure Emotional State

- Heartbeat & Blood Pressure (心拍数、血圧)
- Pulse Wave (脈波)
- GSR(galvanic skin response, 皮膚電気反応)
- Eye movement (眼球運動)



BPニュースセレクト

「恋人との相性チェックに」、ロームが指輪型脈波センサーを開発

2010/10/7 7:00

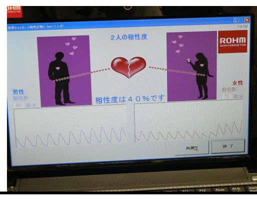
小 中 大 印刷

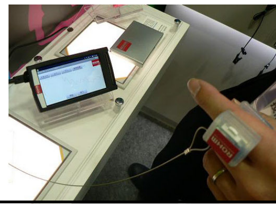
ロームは，大きさが指輪サイズと小さい脈波センサを「CEATEC JAPAN 2010」(2010年10月5～9日，幕張メッセ)に出展した。ヘルスケア機器のほか，ゲーム機や音響機器などアミューズメント分野に向けて開発中のものである。展示ブースでは，ストレス度の測定や恋人との相性チェックに応用したデモンストレーションを披露している。

画像の拡大

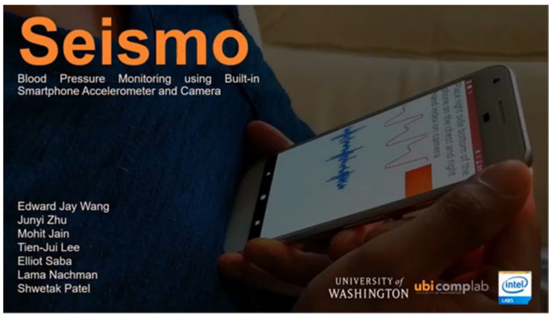
測定の様子

この脈波センサは，LED光を指に当て，反射光または透過光をフォトダイオードで受け取ってヘモグロビン流量の変化を検出するもの。LED光には黄緑色光などが使えるという。取得したデータを無線送信するためのモジュールも搭載する。村田製作所が出展中の指輪型パルスメータと同様の構成だ。



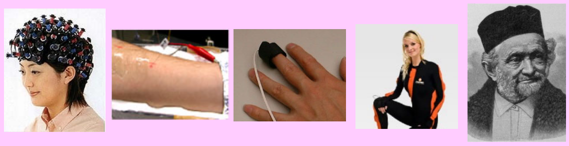


Seismo: Blood Pressure Monitoring using Built-in Smartphone Accelerometer and Camera (CHI2018)
Edward Jay Wang, Junyi Zhu, Mohit Jain, Tien-jui Lee, Elliot Saba, Lama Nachman, Shwetak N Patel



- スマートフォンを胸に押し当てた状態で計測．加速度センサで心拍が計測でき，カメラへの指の押し当てで指先の血流変化が計測できる．結果として心拍から指先の脈動にかかる時間が分かるので，血圧を推定できる．

人間計測手法／Measuring Human



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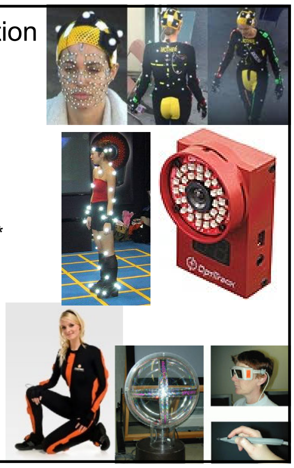
行動計測／Measuring Motion

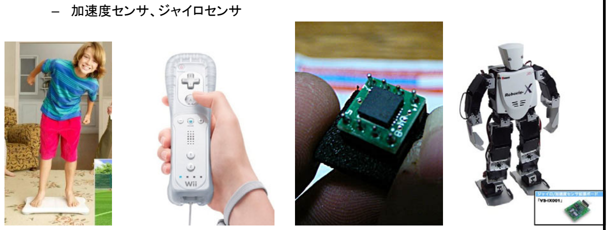
- Motion Capture System
  - 光学式／Optical
  - 機械式／ Mechanical
  - 磁気式／Magnetic
  - ビデオ式／Image Processing*
- 一長一短／Pros and Cons
  - 遮蔽問題／Occulusion
  - ワークスペース／Workspace
  - 金属の影響／Effect of Metal

*KINECT等の詳細は後の回で



Simpler

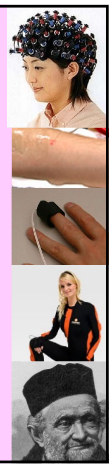
- Gaming controllers can be used as a measuring device.
  - 重心動揺計測⇒Wii Balance Board
  - 運動計測⇒Wii Remote
  - 全身運動など：KINECT, Leap Motionなどの台頭
- 簡単なものは自作可能
  - 加速度センサ、ジャイロセンサ



Sensors became ubiquitous

- For example, simple “touch-panel” is a type of gesture interface, which is very easily available today.
- Many researches on Human-Computer Interaction focuses on how to use simple sensor and guess the intention of the user, by machine learning.

Today’s Summary



Measurement of Human perception is neccesary for interactive system design.

- 脳活動計測／Measure brain activity.
- 神経・筋活動計測／Measure nerve activity.
- 自律神経系計測／ Measure autonomic nerve related phenomenon.
- 運動計測／Measure motion.
- 心理物理実験／Ask the user (psychophysics)

They can be used both as a **evaluation tool**, and **part of an interactive system**

小テスト／Mini Test 次回開始までに提出

https://goo.gl/forms/85xfExX2mLheNncR2

以下の全てに100字以内程度で解答せよ／Answer all questions within 50 words

1. EEGについて説明せよ Explain EEG
2. MEGについて説明せよ Explain MEG
3. MRIについて説明せよ Explain MRI
4. PETについて説明せよ Explain PET
5. NIRSについて説明せよ Explain NIRS
6. 有髄神経と無髄神経の違いについて述べよ Describe difference between myelinated and unmyelinated nerves.
7. 交感神経の活動で生じる現象を3つ挙げよ Quote three phenomena related to SNS(Sympathetic nervous system) activity.

Handouts on the web(再掲)

http://kaji-lab.jp/ja/index.php?people/kaji/interactive

–現在は2018年版がおかれています。徐々に変えていきます。
–梶本研→メンバー→梶本→講義→インタラクティブシステム特論
–Temporary, 2018 version. Will be replaced progressively.

–**こちらのpdfには動画のリンク先(Youtube等)が埋め込まれているので、紙資料よりも便利。紙資料は配布せず、講義の1時間前までにアップロードします。必要なら事前にダウンロードしてください**

–**From next time, lecture handouts will be online 1 hour before the lecture. Print it if necessary.**