KBM – Biofeedback Applications

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Outline

- Organisation
- Last week
- Interactive Therapy with Instrumented Footwear
- Garment as devices
- A Brain Computer Interface with Online Feedback

Biometric measures – summary

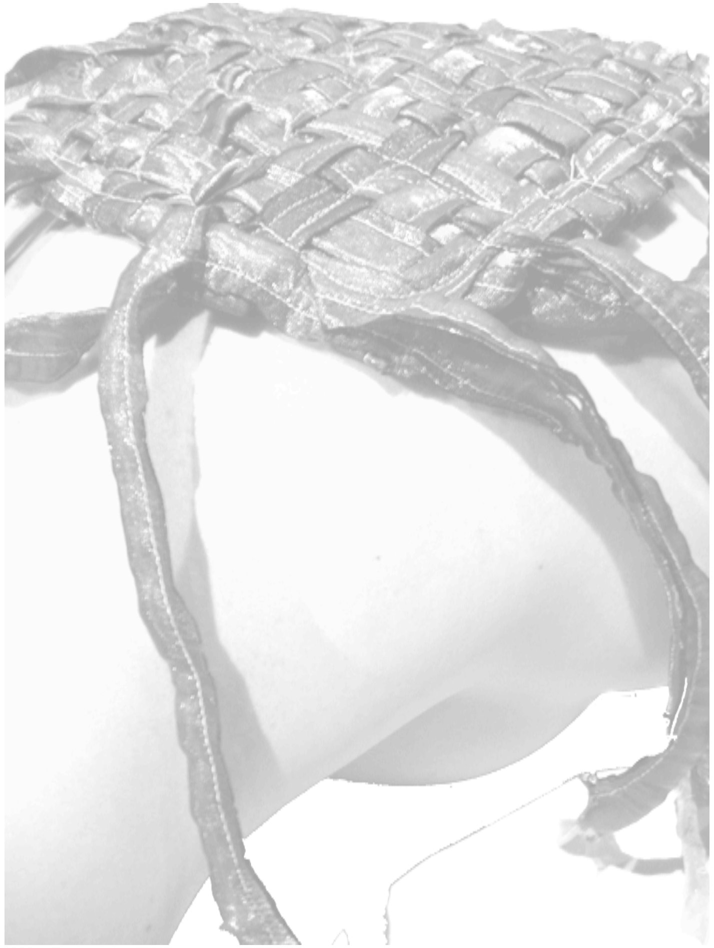
Investigated

The importance of biometric data in particular haptics

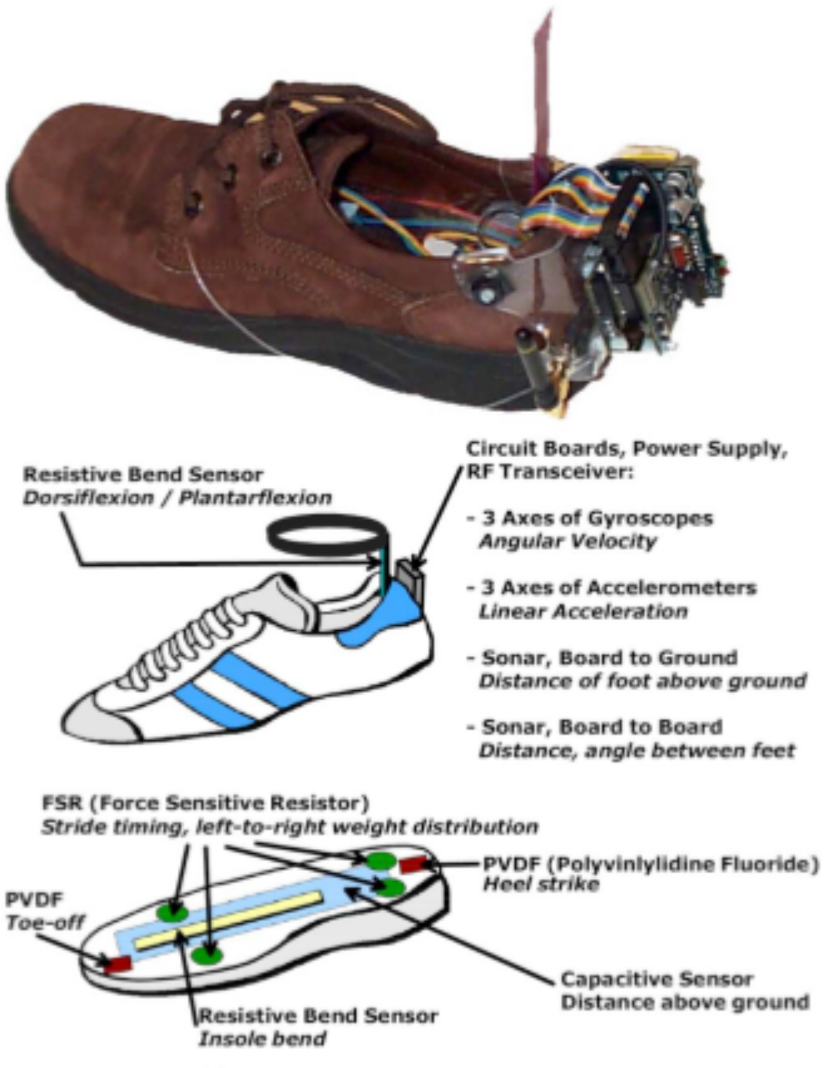
Findings

- Biofeedback allows the creation of feedback mechanisms.
- Modelling of physical phenomenon, such as pressure and object collision are required for making use of haptic measurements.
- GSR provides the means to detect emotional pattern
- Correlation between GSR pattern and emotion needs to be defined, as GSR represents similar emotions alike.

Biofeedback – Applications



Interactive Therapy with Instrumented Footwear (Paradiso et al.)

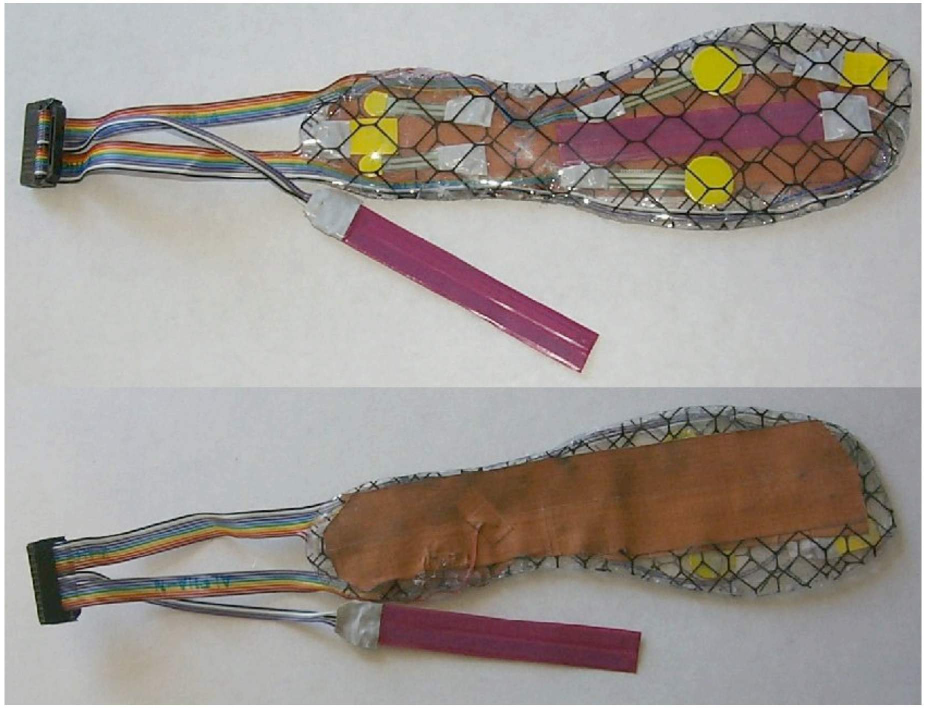


Problem
Make use of musical feedback as aid for learning to move properly.

Domain
Physical therapy, sports medicine, or training.

Aim:
Appropriately instrumenting the body to detect the correct/ avoidable motion and mapping its characteristics causally onto an interactive musical stream, so that a patient can be encouraged to move properly.

Interactive Therapy with Instrumented Footwear



Measurement

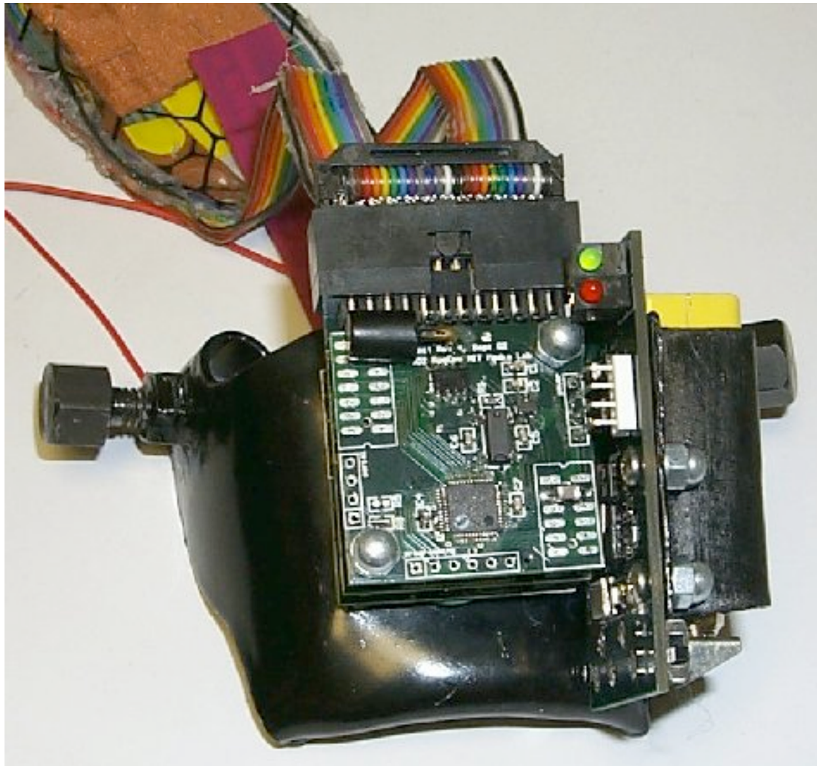
Laminated between two 0.02 inch sheets of clear Type 1 PVC heavy-duty film sheets:

- 4 FSR pads (force sensitive resistors that measure continuous pressure),
- 2 PVDF strips (polyvinylidine fluoride that measures dynamic pressure),
- 2 pairs of resistive bend sensors.

Knowledge:

FSRs provide a coarse measurement of the pressure distribution.
Each pair of bend sensors provides information about bi-directional bend.
One pair provides information about the extent of plantarflexion or dorsiflexion at the ankle.
The other pair of bend sensors provides information about the extent of plantarflexion or dorsiflexion at the metatarsals during walking

Interactive Therapy with Instrumented Footwear



Shoe attachment

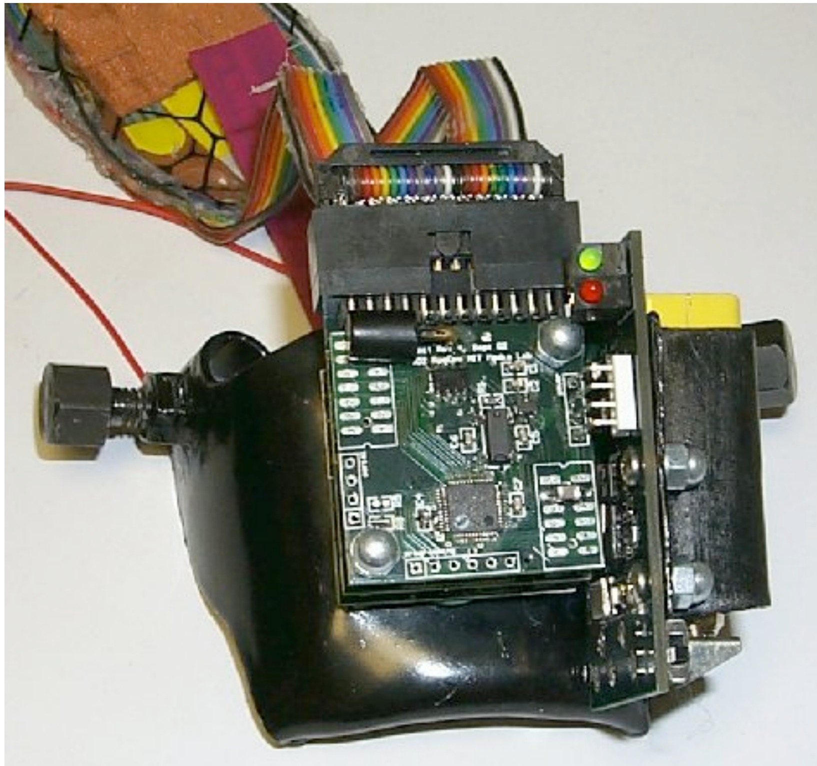
3 stacked circuit boards,
the power supply (a 9V battery),
the antenna for wireless transmission.

Weight: approximately 300 g.

Each circuit board address specific needs:

- one contains the conditioning electronics for the insole sensors,
- the second has the microcontroller that collects data from the other boards together with the wireless transceiver,
- the third has a full set of three gyroscopes and three accelerometers to measure angular velocity and linear acceleration about three axes.

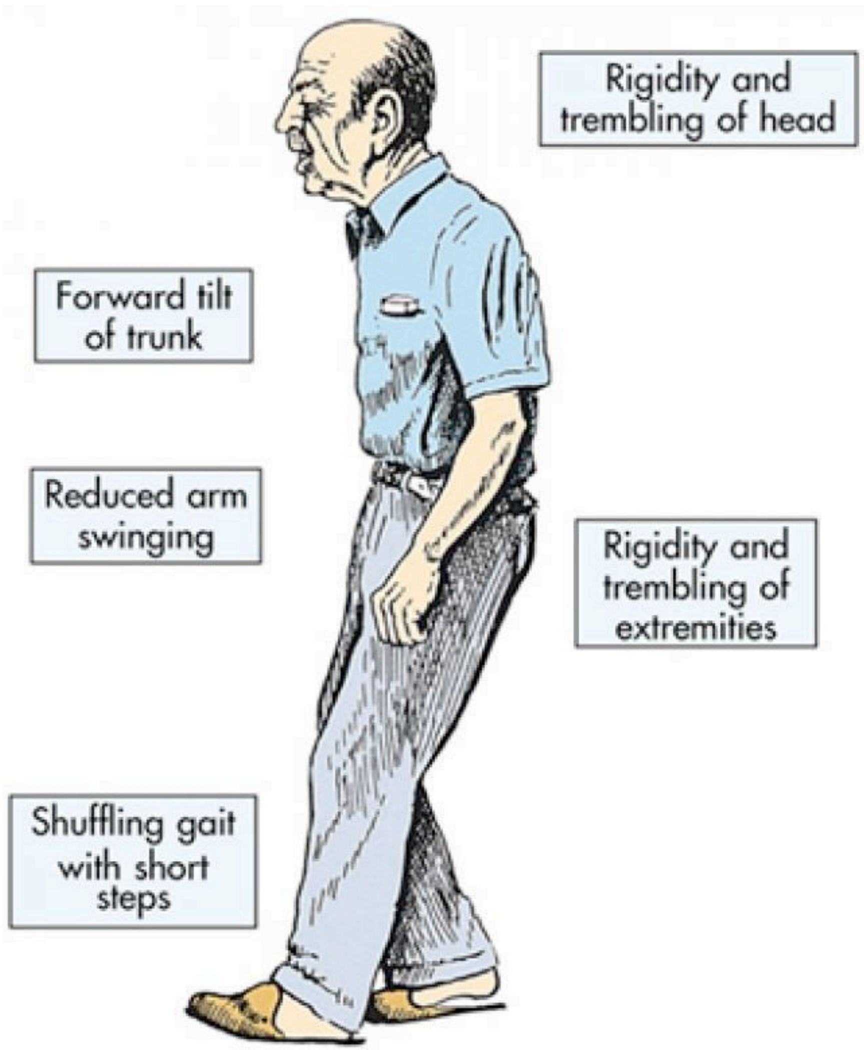
Interactive Therapy with Instrumented Footwear



Shoe attachment

A processor/RF Stack card acquires and serializes all data, then transmits at 115 kbits/sec via a simple time devision multiple access (TDMA) scheme, allowing full state updates at 75 Hz per shoe.

Interactive Therapy with Instrumented Footwear



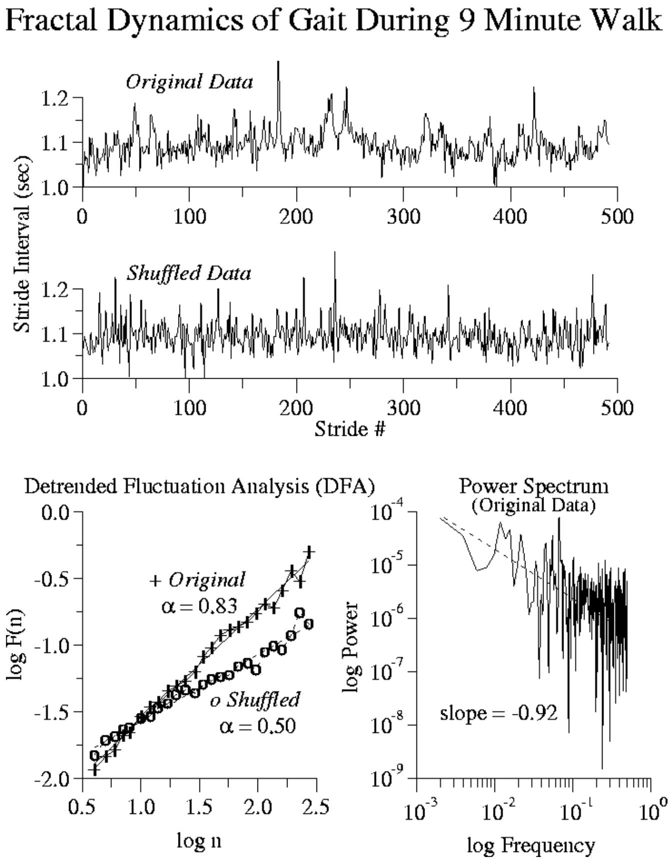
Real-time musical feedback therapy

Disease: Parkinson

Problem:
chronically stunted walk and spontaneous break into a slow shuffling (festination).

Solution:
sensor signals to be algorithmically combined and processed, then coupled into a wide range of parameters that modify sequenced music in real time.

Interactive Therapy with Instrumented Footwear



Real-time musical feedback therapy

Derived gait rhythm and quality by looking at the load transfer between the front and back pair of insole pressure sensors.

An onset of significant gait arrhythmia or shuffling
=> a loud metronome click was produced to cue the patient back to a steady pace.

Introduction of ambient music, continually providing subtle rhythmic cues.

Detection of gait defects
=> the music became less melodic and strongly rhythmic, encouraging the wearer to walk at pace, at which point the pedestrian background music would resume (reward is regain of a pleasant sonic backdrop when the gait normalized).

Interactive Therapy with Instrumented Footwear

Real-time musical feedback therapy

Physical therapy while recovering from an injury:

Preventing over-pronation or over-supination (when the dynamic foot load is biased more to one side or the other) and regulating the maximum distributed plantar pressure.

Detecting a pronating or supinating gait,
=> the musical stream is altered in proportion to the condition's severity – i.e., the key gradually modulates from major to minor, then progressively becomes dissonant.

Garments as devices (Schiphorst et al.)

communication, expressivity, interaction

body area networks
a platform for future applications in smart clothing

collaboration
bridging the smarts between textiles and fashion

wearables for the telepathically impaired
communicating with biometric data

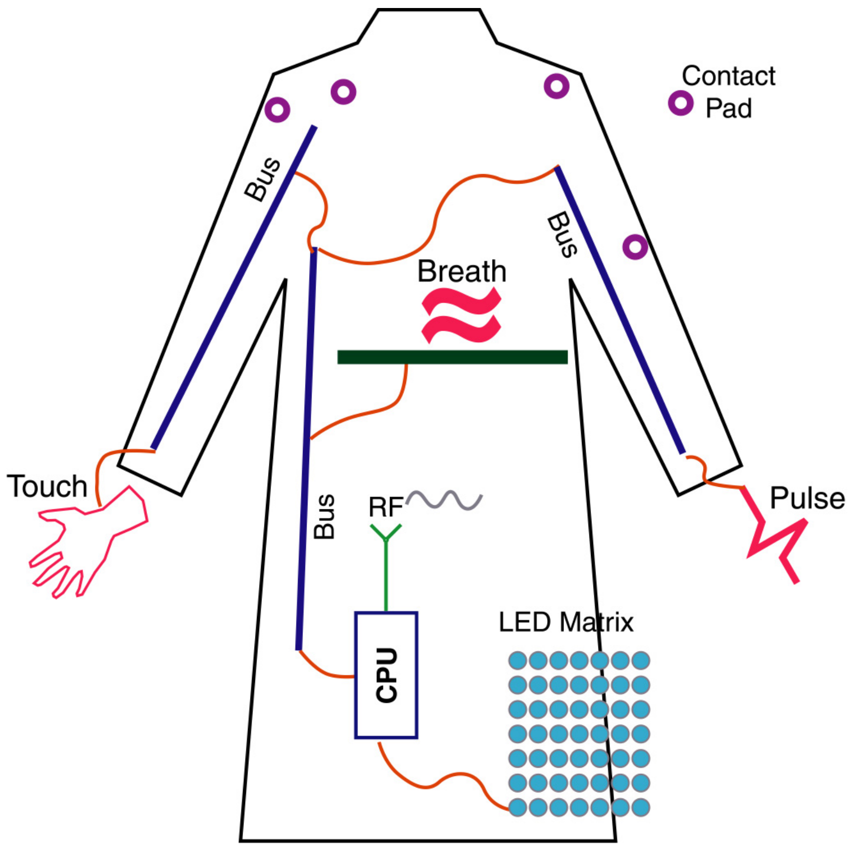
Garments as devices (Schiphorst et al.)

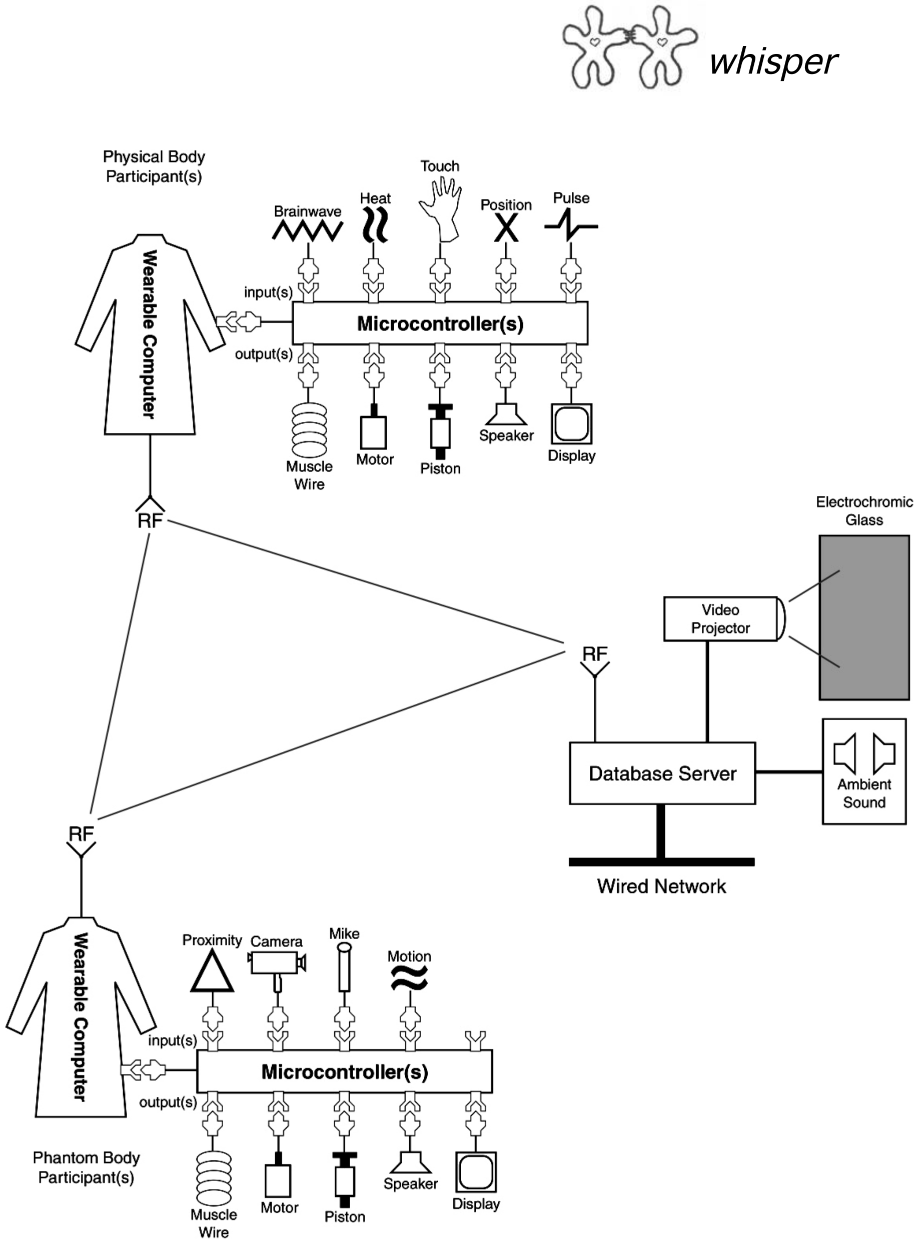
clothing is ambient and expressive in

- what it reveals
- what it conceals

mobility and integrated garments for freedom of movement

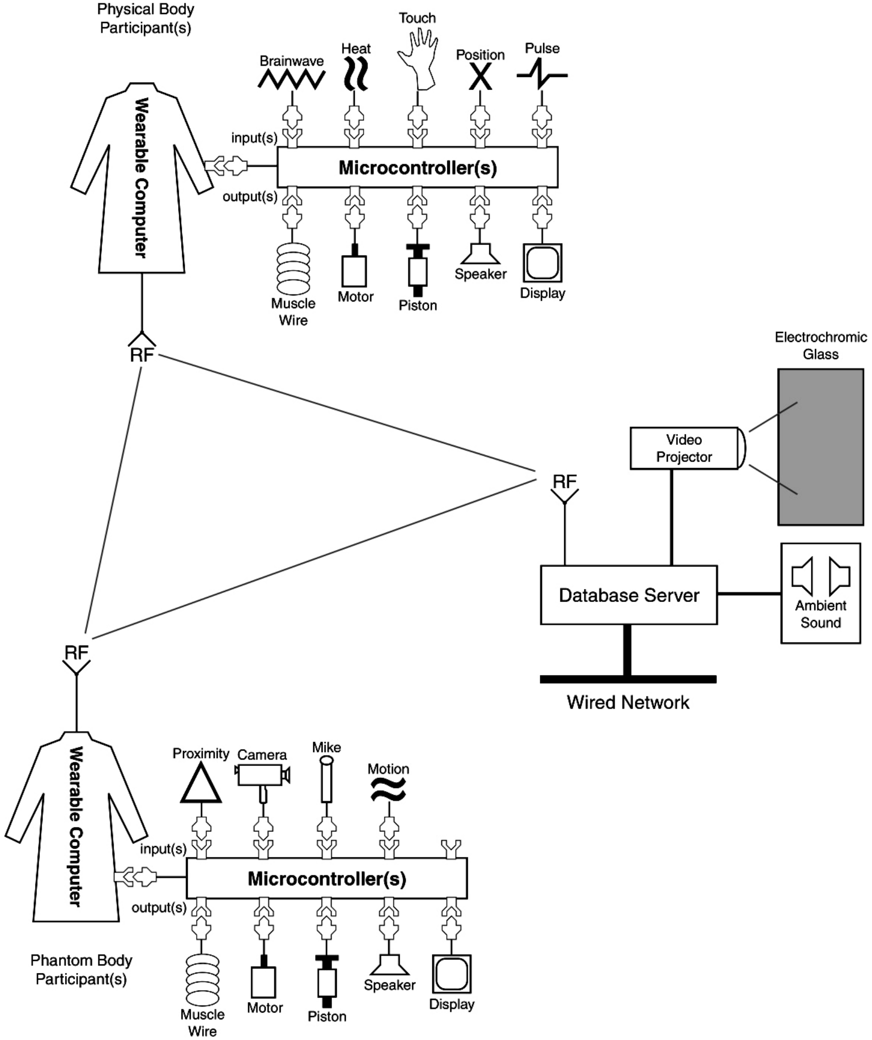
Garments as devices (Schiphorst et al.)





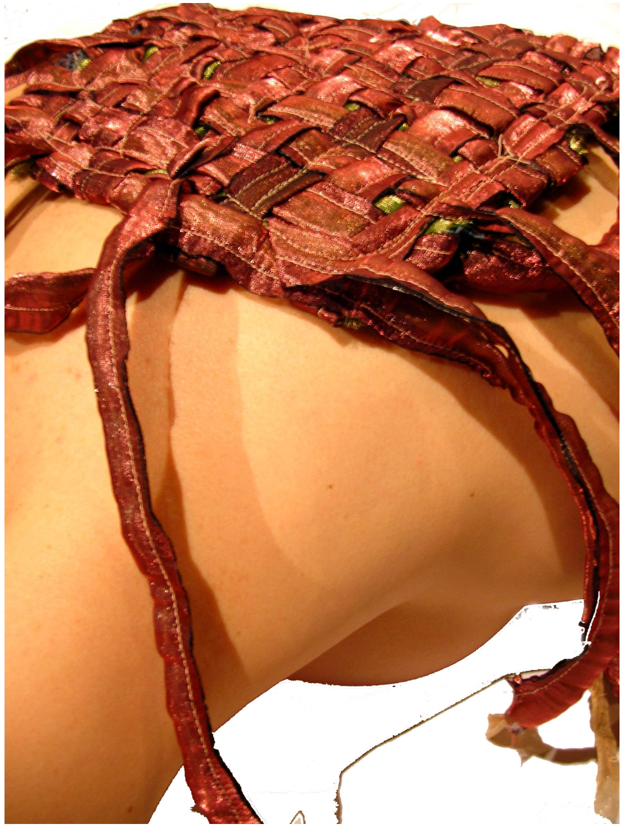
Garments as devices (Schiphorst et al.)

whisper



Garments as devices (Schiphorst et al.)

Exhale



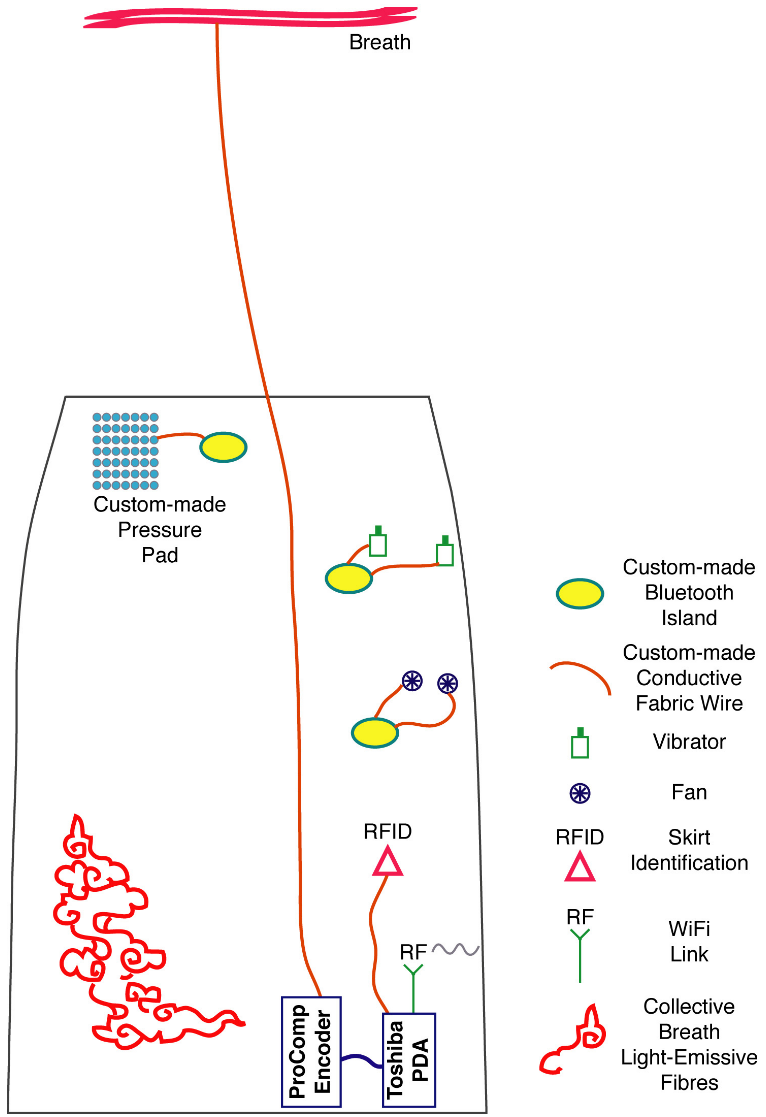
a public installation utilizing wearable technologies

breath as empathetic interaction

breath is a source of information as well as a pattern to communicate that information

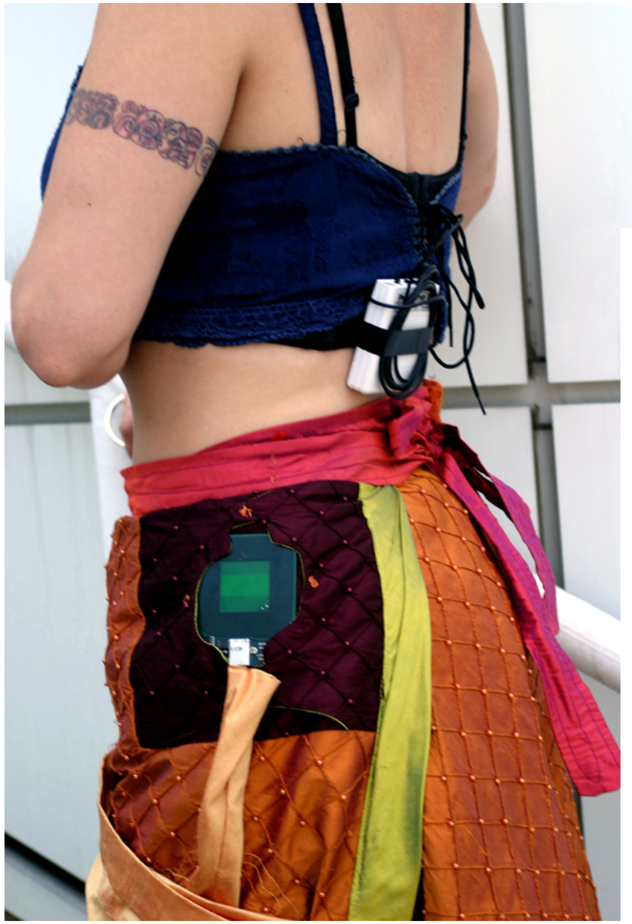
Garments as devices (Schiphorst et al.)

Exhale



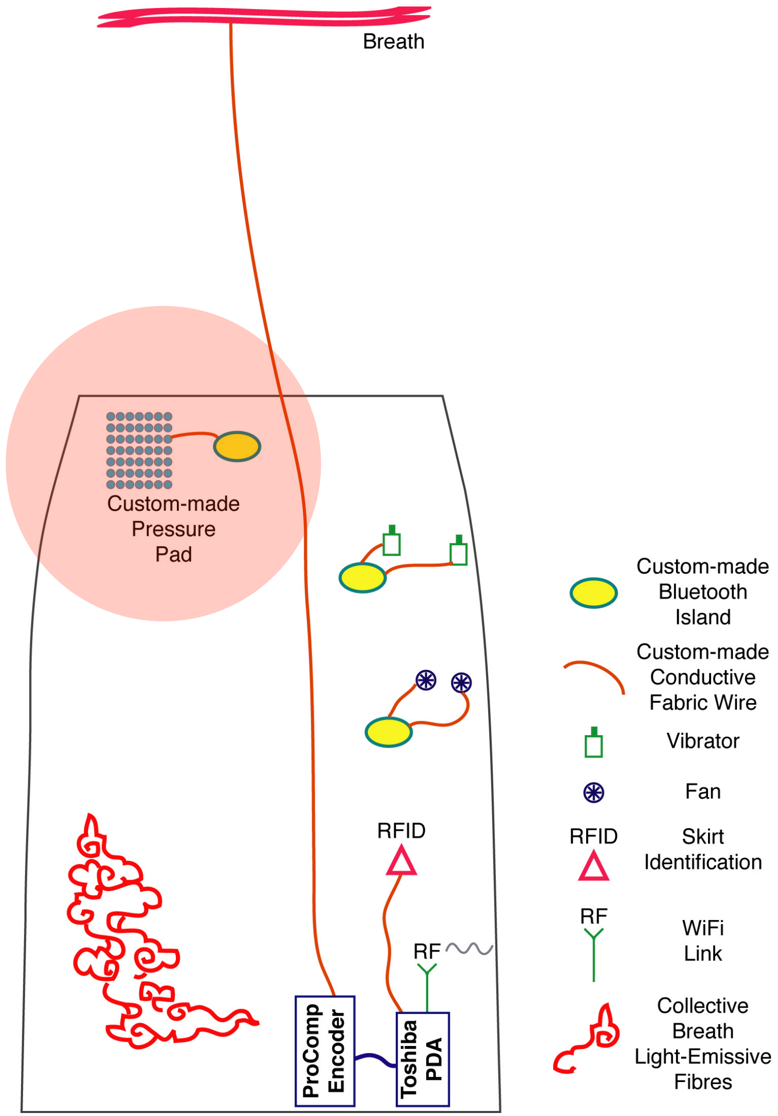
Garments as devices (Schiphorst et al.)

Exhale



self-2-self
self-2-other
self-2-group

Garments as devices (Schiphorst et al.)



Soft gestural recognition
flexible displays

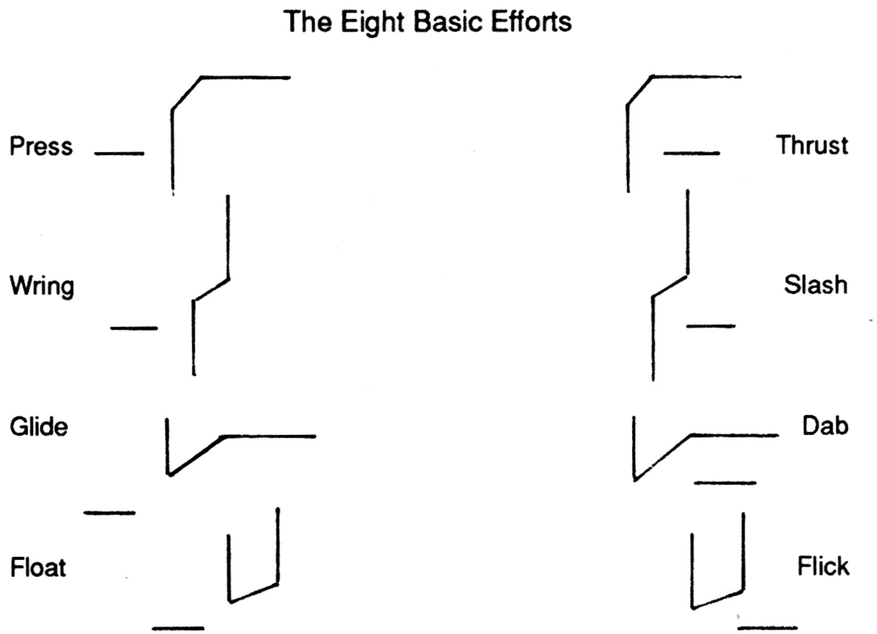
Utilizing the fabric surface as a
tactile interface

A defined set of qualitative tactile
gestures using heuristic algorithms

Garments as devices (Schiphorst et al.)

whisper

Multiple touch heuristics



Based on the 4 inter-related LABAN categories:
Body/ Effort/Shape/Space

Garments as devices (Schiphorst et al.)

whisper

Tactile efforts quality

touch-effort	Description
tap	A soft, short, small, touch, usually rendered with a single finger.
pat	A bigger version of “tap” and a soft version of “slap”. Usually rendered with an open hand or palm.
hold	A lingering, soft, big, touch. A “hold” has an encompassing feel.
touch	“Touch” is a small version of “hold”. It is an indication of comfort and is rendered with the fingers, hand, or palm.
stroke	A traveling touch, soft but directional, rendered with fingers, hand or palm.
glide	A traveling, meandering, touch. Soft and directionless and rendered with the fingers, hand, or palm.
jab	A hard, short, small, touch. A hard poke by a finger or blunted object. Also known as “poke”.
knock	A medium-sized, fist against, rapping hard. In our scheme, it is different than “jab” and “slap” in size only.
slap	An open-handed, hard, short, touch. In our scheme, a large version of “jab” and “knock”.
press	This is a long, hard, touch.
rub	This is a moving, hard, touch.
knead	Kneading involves many fingers moving hard and in a slightly wandering fashion.
other touch-	efforts not attempted in this system:
punch	This is like a “knock”, but is different in intensity and slightly different in timing.
flick	This is like a “jab”, but is slightly different in shape over time. A “flick” travels slightly in relation to a “jab”, which is more stationary.

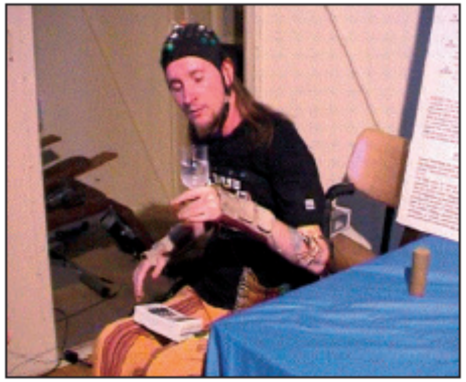
Garments as devices (Schiphorst et al.)

whisper

Parameter extraction

Parameter:		Description
pressure	soft-hard	The intensity of the touch.
time	short-long	The length of time a gesture takes.
size	small-medium-big	The size of the part of the interaction object that touches the pad.
number	one-many	The distinction between one finger or object and many fingers.
speed	none, slow-fast	The speed of a touch-effort. This is the overall velocity of movement. This parameter is not used directly to distinguish efforts, but is used to determine space.
direction	none, left, right, up, down, and four diagonals	The direction of movement. This parameter is not directly used to distinguish efforts, but is used to determine space and path.
Secondary:		
space (speed)	stationary-traveling	A function of speed. If speed is zero then the gesture is stationary, otherwise it's traveling.
path (direction)	straight-wandering	If the speed is not zero, and there is only one direction registered, the gesture is straight.
disposition (pressure)	constant-varying	If the pressure maintains a single value after an initial acceleration the gesture is constant, otherwise it's varying.
pattern (gesture)	continuous-repetitive	If a gesture is unique in relation to the gesture immediately before and after, it is continuous. Any repeated action or gesture is classified as repetitive.

Brain Computer Interface (see reference list)

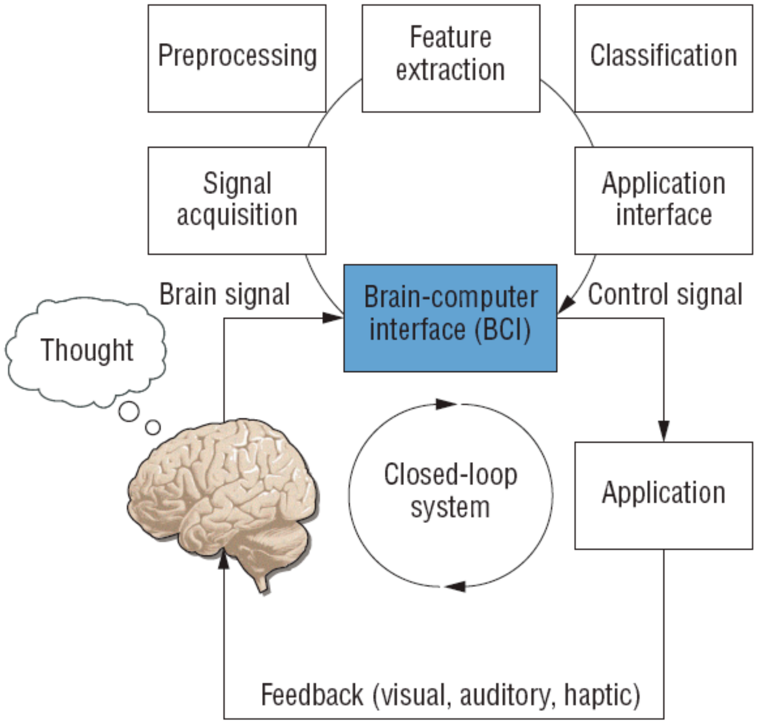


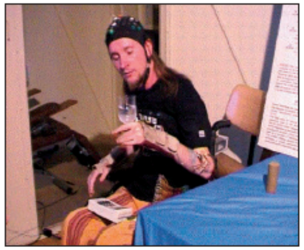
Goal of BCI

Facilitate a brain computer in-build communication and control systems that a person can use to interact with the environment without the need for muscular or peripheral neural activity.

The principal application of a BCI is as a form of neural prosthesis for people suffering from severe paralyzing conditions which can be caused by, for example, Amyotrophic Lateral Sclerosis (ALS).

Brain Computer Interface (see reference list)





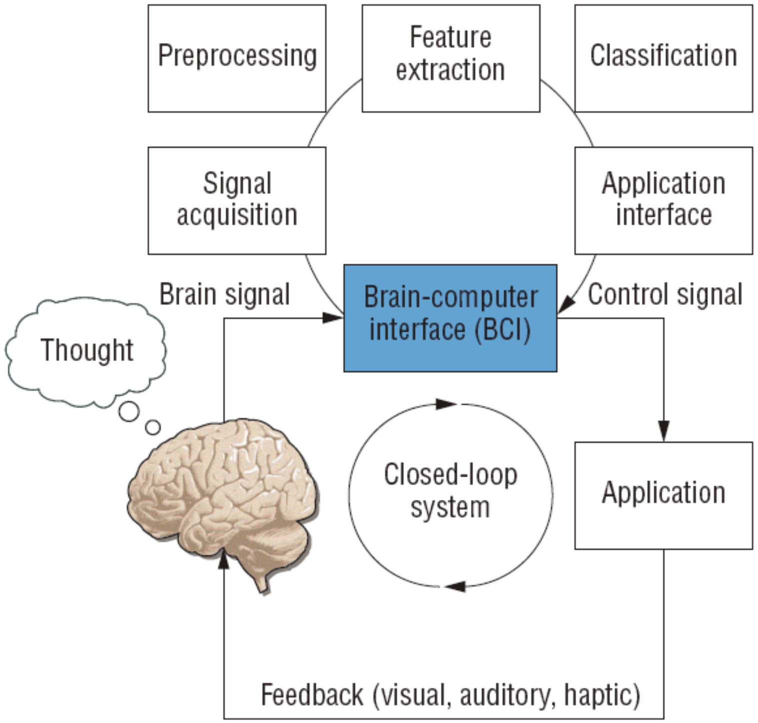
Signal acquisition

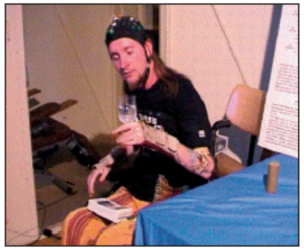
Invasive (place electrodes directly on or inside the cortex).

Noninvasive
EEG (Electroencephalography)
MEG (magnetoencephalography),
NIRS (near-infrared spectroscopy)
fMRI (functional magnetic resonance imaging) [8].

MEG and fMRI equipment is large and expensive, which limits the practical application. NIRS and EEG is small and affordable.

Brain Computer Interface (see reference list)



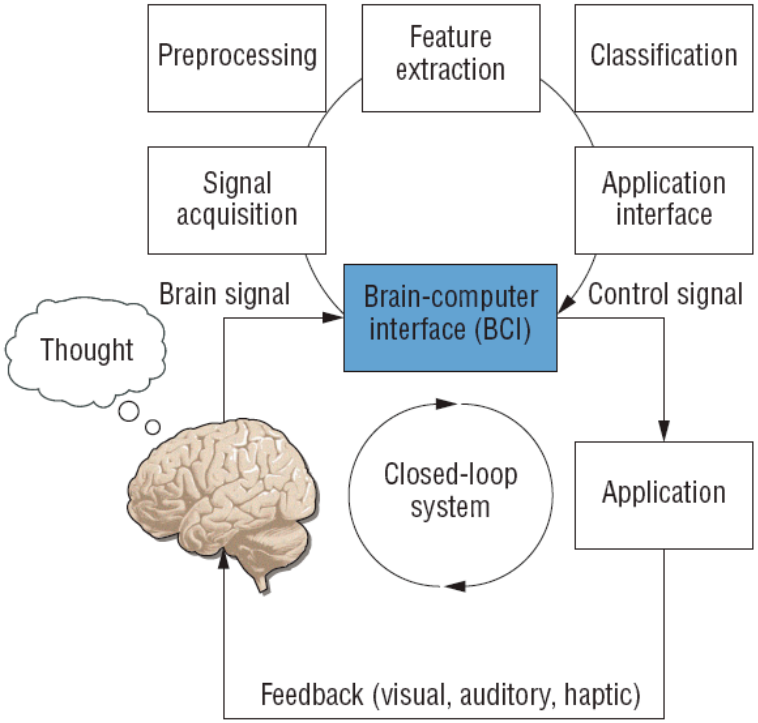


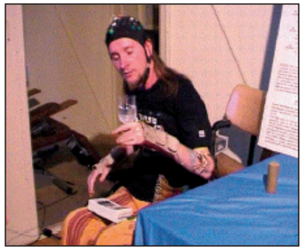
Mental strategy

Operant conditioning is a learning process with the goal of self-regulating brain potentials (such as slow cortical potential shifts) or brain waves (such as sensorimotor rhythms) with the help of suitable feedback.

Motor imagery activates cortical areas similar to those activated by executing the same movement. Consequently, we place the EEG electrodes over the primary sensorimotor areas.

Brain Computer Interface (see reference list)



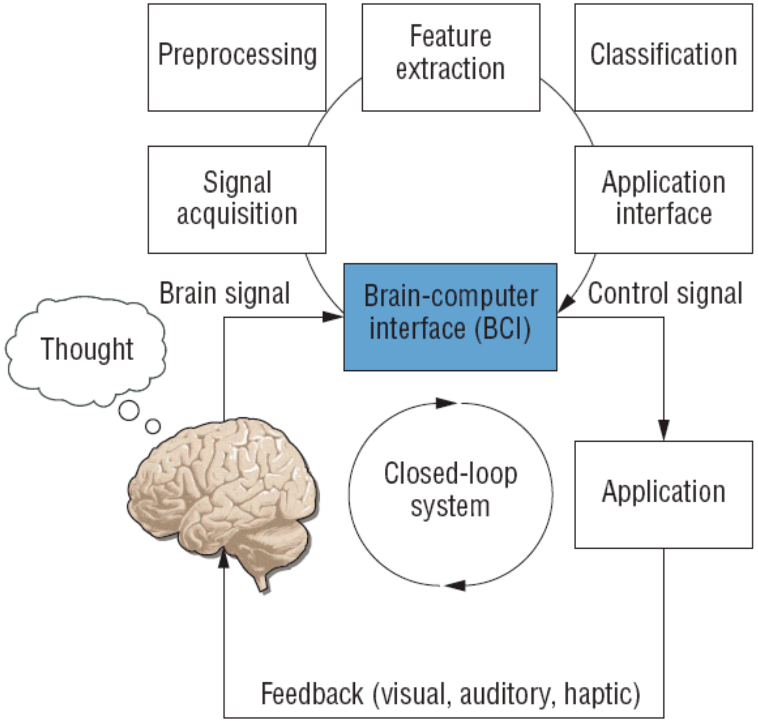


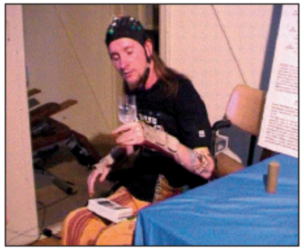
Mental strategy

Other mental tasks suitable to modulate the brain signals:

- mental arithmetic
- imaging the rotation of geometric objects.
- focused attention or gaze control on visual stimuli (e.g. flickering lights or flashed letters)

Brain Computer Interface (see reference list)



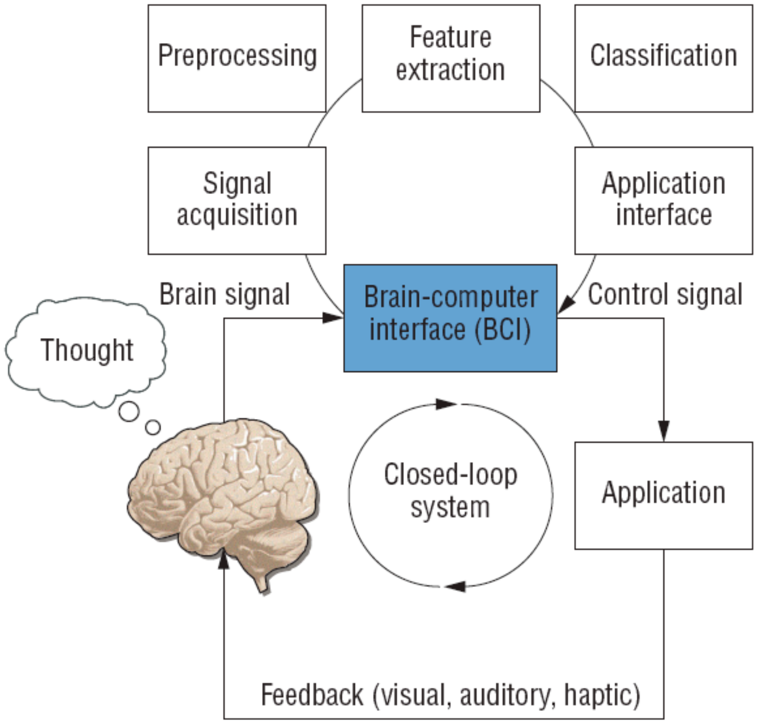


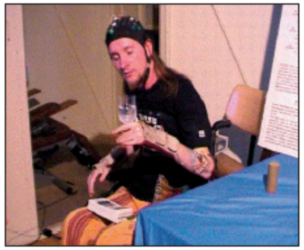
Self-based BCI

Asynchronous (sample by sample)

- system is continuously available to the user
- the user decides freely when to generate a control signal
- such a system is complex and demanding => maximize the intentional control (true positives) while minimizing the non-intentional control (false positives)

Brain Computer Interface (see reference list)



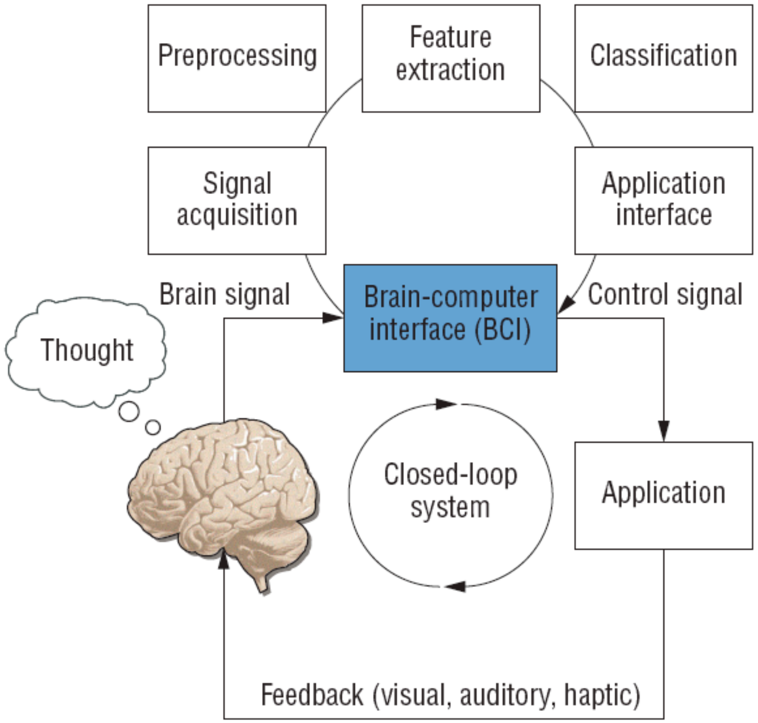


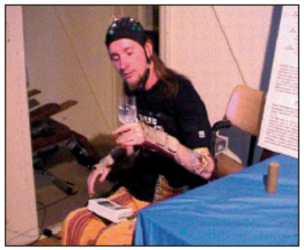
Cue-based BCI

Synchronous (a predefined time window of some seconds following a cue stimulus)

The cue might let users know whether they should imagine moving the left or right hand during training.

Brain Computer Interface (see reference list)





Training and feedback

Users first go through several training sessions to obtain control over their brain potentials (waves) and maximize the classification accuracy of different brain states (cue-based).

This learning process is highly subject-specific, so each user must undergo the training individually.

The learning phase produces a classifier that can be used to classify the brain patterns online and provide suitable feedback to the users. Visual feedback has an especially high impact on the dynamics of brain oscillations.

Brain Computer Interface (see reference list)

Brain controlled wheelchair

Potential approach:

Evoked BCI

=> exploits a strong characteristic of the EEG, *which reflects* the immediate automatic responses of the brain to some external stimuli.

Evoked potentials are easy to detect with scalp electrodes.

BUT

Evoking potentials requires external stimulation, so they apply to only a limited task range.

Brain Computer Interface (see reference list)

Brain controlled wheelchair

Chosen approach:

Spontaneous BCI

=> based on the analysis of EEG phenomena associated with various aspects of brain function related to mental tasks that the subject carries out at will (imagine limb movements, performing cognitive activities).

Plus

The subject has to also make self-paced decisions. In this asynchronous protocol, the subject can send the appropriate mental command at the right time to make the wheelchair turn and cross the desired doorway while it's moving continuously.

Brain Computer Interface (see reference list)

Brain controlled wheelchair

Chosen approach:

Machine learning (statistics on the Bereitschaftspotential (BP) or Readiness Potential (RP) of the movement) to discover the individual EEG patterns characterizing the mental tasks users execute while learning to modulate their brainwaves in a way that will improve system recognition of their intentions

The key aspect of our brain-actuated robots is combining the subject's mental capabilities with the robot's intelligence.

The subject delivers a few high-level mental commands (for example, "Turn right at the next occasion"), and the robot executes these commands autonomously (agent) using the readings of its onboard sensors.

Brain Computer Interface (see reference list)

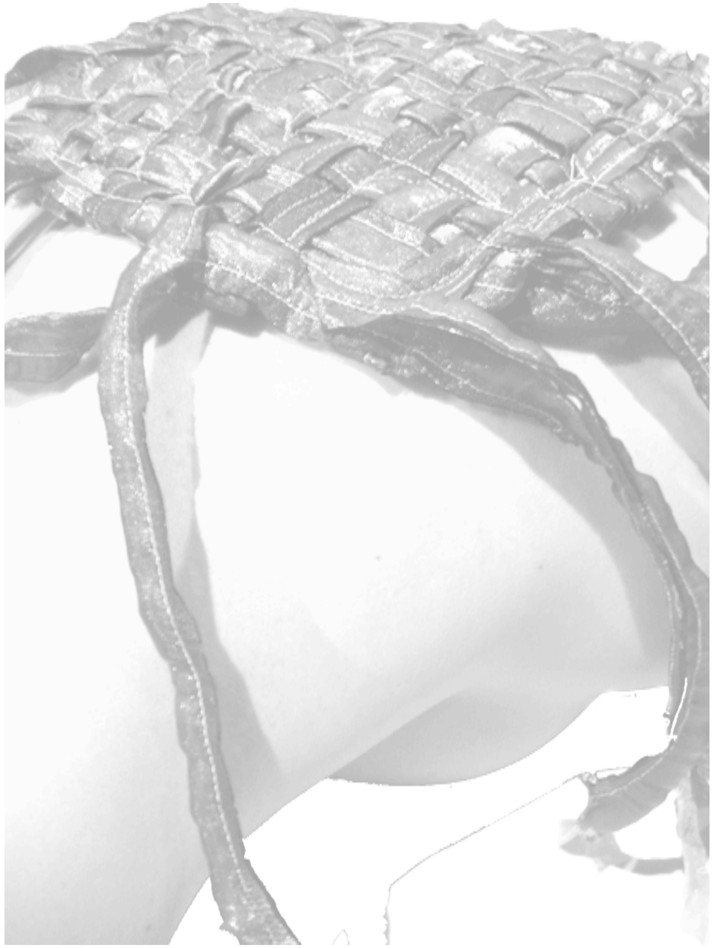
Brain controlled wheelchair

Results:

In a few days, two human subjects learned to mentally drive a robot between rooms in a house-like environment and visit three or four rooms in a prescribed order.

When the subjects later controlled the robot manually along the same trajectories, the performance was only marginally better than the mental performance.

Haptic – References



Biometric Applications – References

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