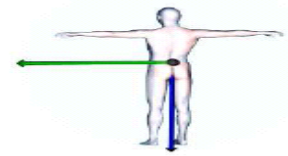


# Application of Artificial Intelligence in Medicine

**Daniel Novák**

**20.5.2014**



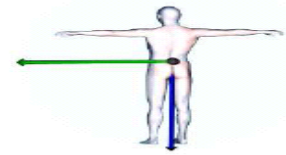


# Content

- Expert Systems
- Case studies in medicine
- Telemedicine system
  - Biological data processing
    - Examples from machine learning
  - Ambient assisted living



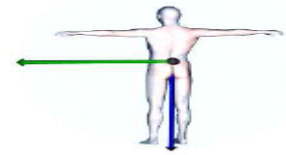
# What is an ES?



- **Expert System (ES)** is a branch of Artificial Intelligence that attempt to mimic human experts.
  - Expert systems can either support decision makers or completely replace them.
  - Expert systems are the most widely applied & commercially successful AI technology.



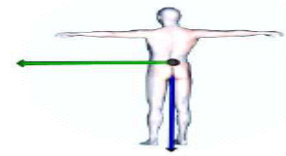
# What is an ES?



" . . . An intelligent computer program that uses knowledge and inference procedures to solve problems that are difficult enough to require significant human expertise for their solution."



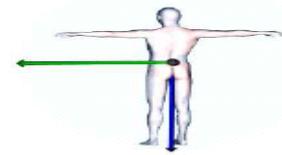
# Expert System



- Attempt to model expert decision making in a limited domain
- Examples: medical diagnosis, computer configuration, machine fault diagnosis
- Requires a willing Expert
  - Sometimes communication is difficult
- Requires knowledge representable as rules
  - Doesn't work for chess (**game theory**)



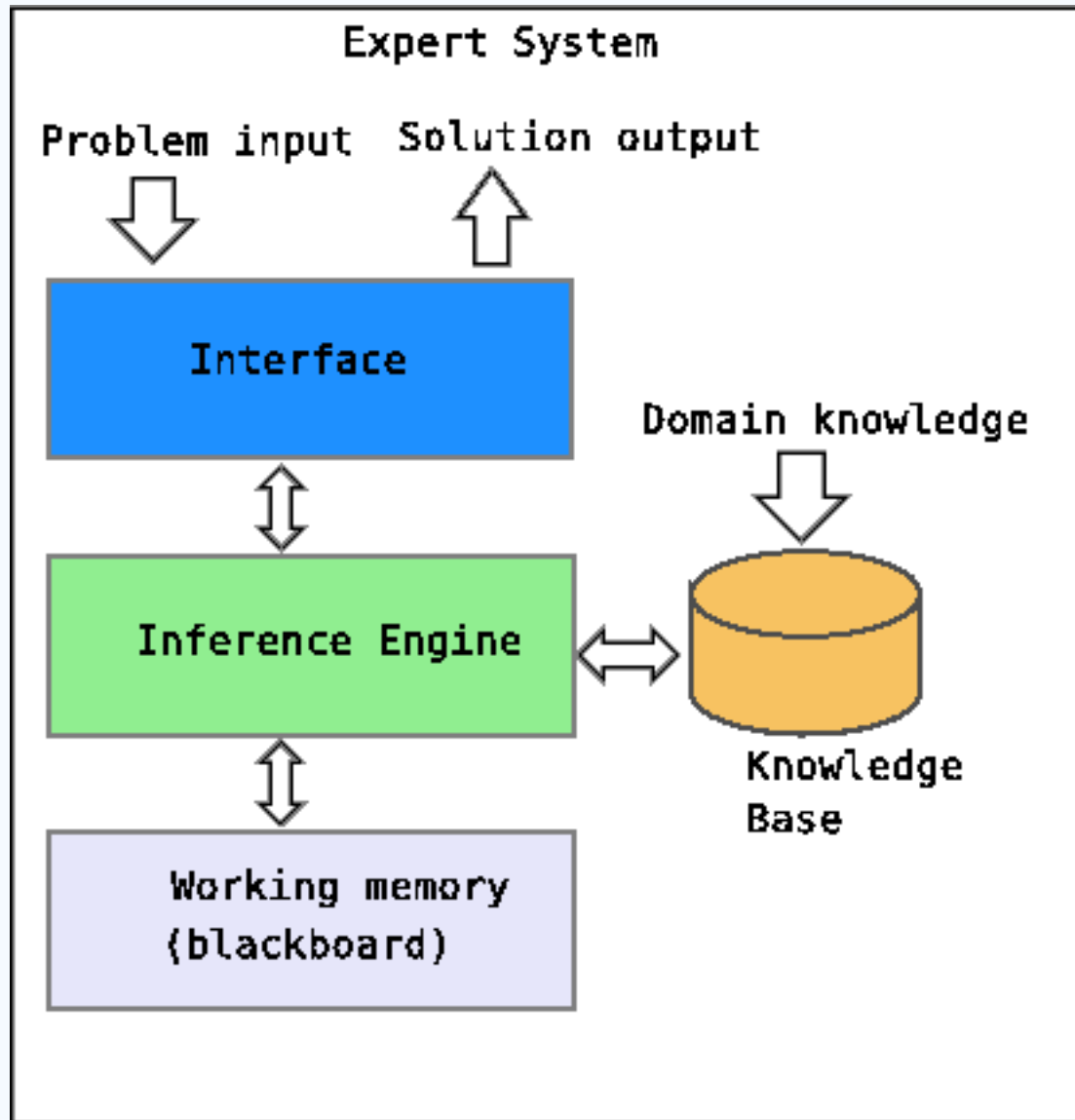
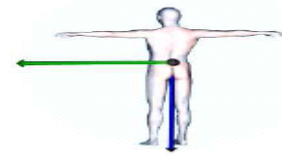
# Conventional and ES



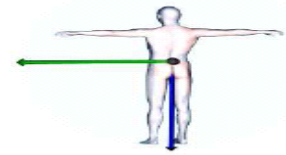
Conventional Systems	Expert Systems
Knowledge and processing are combined in one sequential program	Knowledge base is clearly separated from the processing (inference) mechanism (knowledge rules are separated from the control)
Programs do not make mistakes (only programmers do)	Program may make mistakes.
Do not usually explain why input data are needed or how conclusions were drawn	Explanation is a part of most expert systems
The system operates only when it is completed	The system can operate with only a few rules (as a first prototype)
Execution is done on a step-by-step (algorithmic) basis	Execution is done by using heuristics and logic



# The structure of ES



# The structure of ES



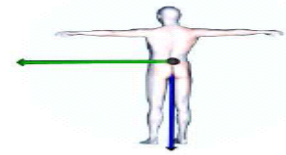
## THE KNOWLEDGE BASE

- The key bottleneck in developing an expert system.
- Contain everything necessary for understanding, formulating and solving a problem.
- It contains facts and heuristics.
- The most popular approach to representing domain knowledge is using production rules.
  - **Rule 1**  
IF car won't start  
THEN problem in electrical system
  - **Rule 2**  
IF problem in electrical system  
AND battery voltage is below 10 volts  
THEN bad battery





# The structure of ES

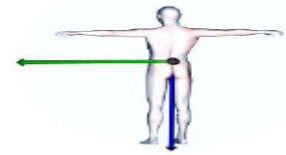


## Blackboard (WORKING MEMORY)

- Contains facts about a problem that are discovered during consultation with the expert system.
- System matches this information with knowledge contained in the knowledge base to infer new facts.
- The conclusion reach will enter the working memory.
- Thus, working memory contain information either supplied by user or infer by the system.



# The structure of ES

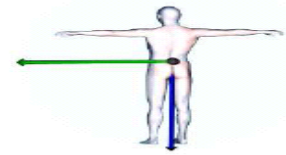


## INFERENCE ENGINE

- Knowledge processor which is modeled after the expert reasoning power.
- Processor in an expert system that matches the facts contained in the blackboard with the domain knowledge contained in the knowledge base, to draw conclusion about the problems.
- It taps the knowledge base and working memory to derive new information and solve problems



# The structure of ES

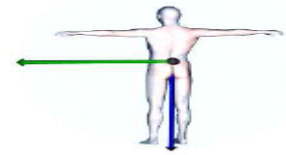


## THE USER INTERFACE

- The user communicates with the expert system through the user interface.
- It allows the user to query the system, supply information and receive advice.
- The aims are to provide the same form of communication facilities provided by the expert.
- But normally has less capability of understanding natural language and general knowledge.



# The structure of ES

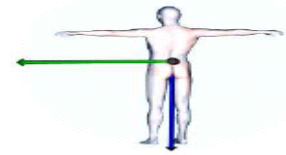


## THE EXPLANATION FACILITY

- A trademark of expert systems: ability to explain their reasoning.
- An additional component of expert system.
- ES can provide explanation on:
  - **WHY** it is asking the question
  - **HOW** it reached some conclusion.



# The structure of ES



## Explaining WHY

– Example:

– MM : Will the car not start?

– Person : WHY

– MM : If I know that the car won't start then I usually

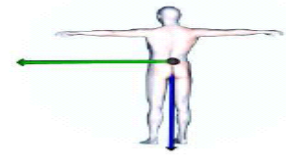
assume the problem is the electrical system.

– Expert responds with what they might conclude from the answer.

– ES respond to a WHY query by displaying the rule it is currently pursuing.



# The structure of ES

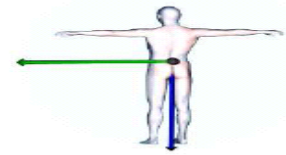


## Explaining HOW

- Besides giving final results, expert system can explain how it arrived at a result.
- Example:
  - MM : The battery is bad
  - Person : HOW
  - MM : Since your car won't start, I assumed there was a problem with the electrical system. I found the battery voltage was below 10, I knew the battery was bad.
- ES respond by tracing back through the rules that fire the conclusion.



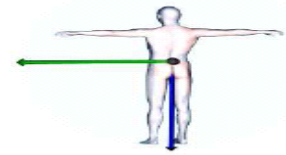
# Knowledge and Uncertainty



- Facts and rules are structured into a knowledge base and used by expert systems to draw conclusions.
- There is often a degree of **uncertainty** in the knowledge.
  - Things are not always true or false
  - The knowledge may not be complete.
- In an expert system certainty factors are one way indicate degree of certainty attached to a fact or rule.



# Knowledge base example



## nodes // definition{

```
Is_petrol /node name{
```

```
'I have petrol'
```

```
(bayesian, // bayes node
```

```
0.5) // apriory prob ( wincf )
```

```
}
```

```
auto_ok {
```

```
(bayesian, 0.6, goal) // goal
```

```
}
```

## rules / {

```
{ is_petrol, auto_ok, 0.6, 0.1 } /rules and weights
```

```
// tj. auto_ok with 0.6 prob, when is petrol
```

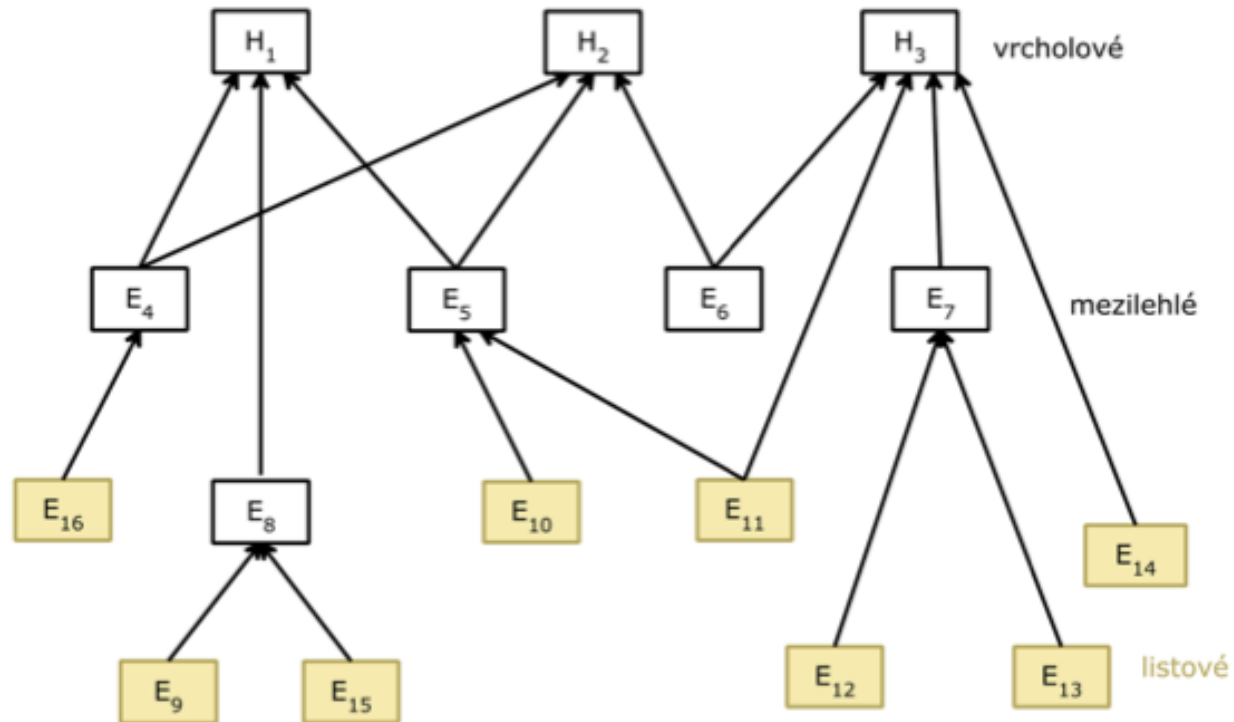
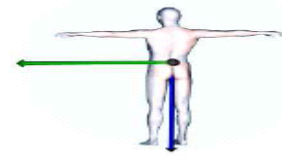
```
// ok with 0.1, when is not petrol
```

```
IF < předpoklad  $E$  > THEN < závěr  $H$  > WITH < váha  $L$  >  
ELSE < závěr  $H$  > WITH < váha  $\hat{L}$  >
```



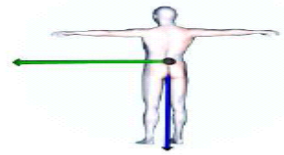


# Inference net

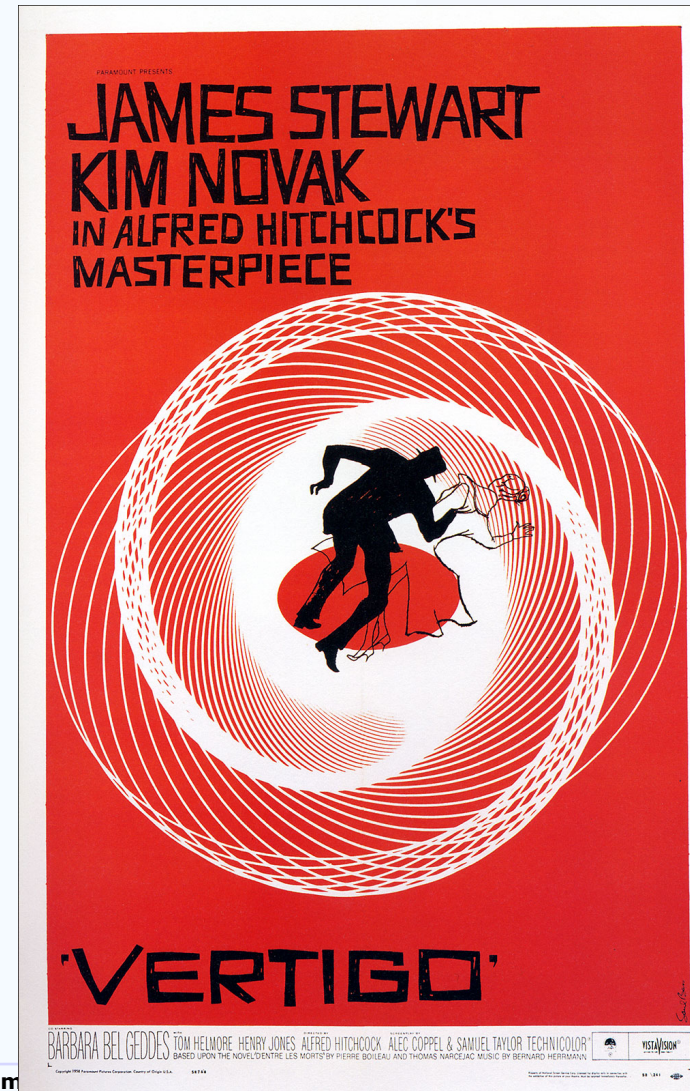


Dotazovatelné × nedotazovatelné

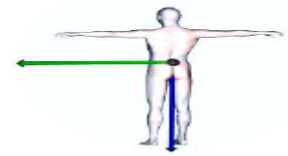
# Example – Vertigo Diagnosis



- diagnosis of vertigo is difficult
  - wide spectrum of causes
  - vague description of the problem
  - only 20% of patients are diagnosed
- correct diagnosis is required
  - risk of accidents
  - risk of developing severe symptoms



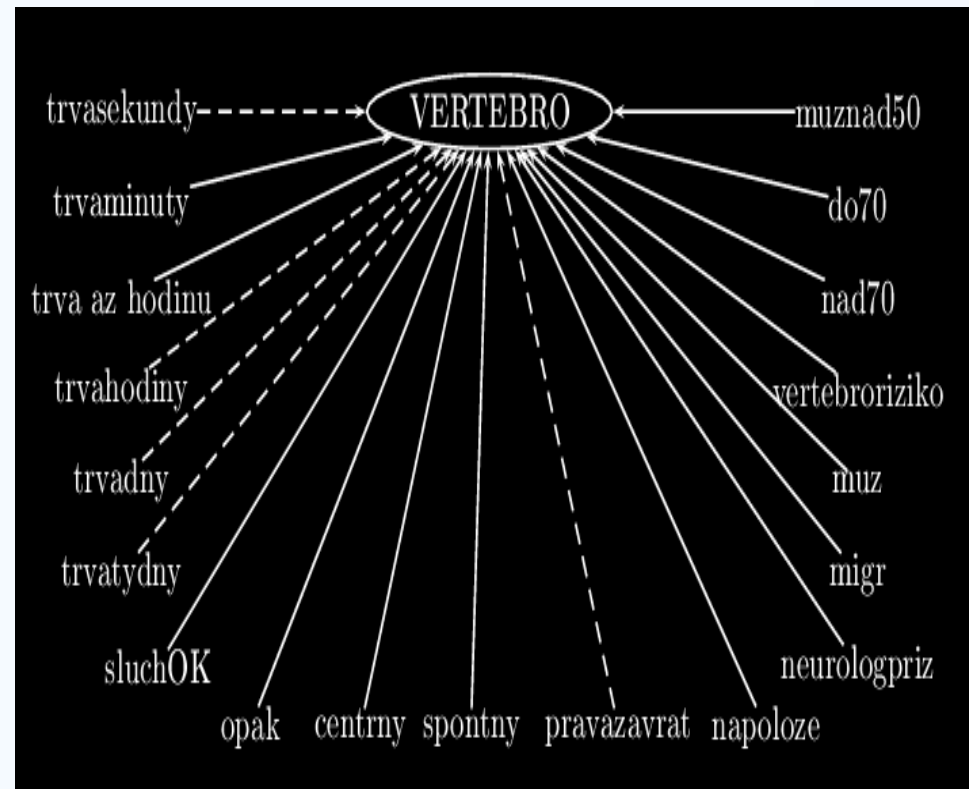
# Vertigo ES

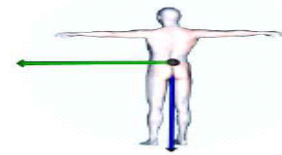


- 13 diagnoses
- 140 rules

## Rules for node VERTEBRO

- 81,5 % in diagnosis of typical cases
- 69 % in diagnosis of untypical cases





# Single DBS Neuron Processing

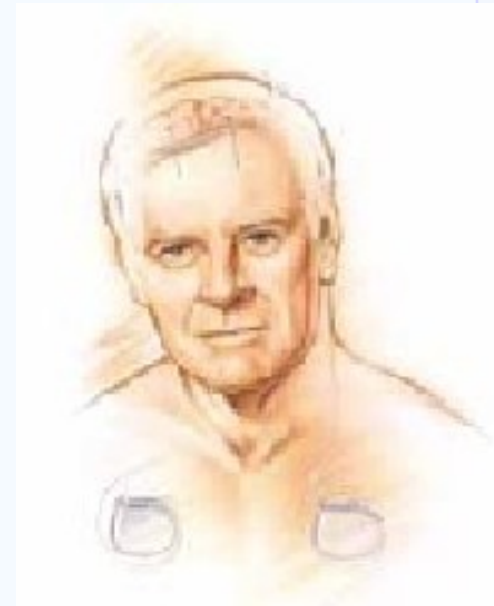
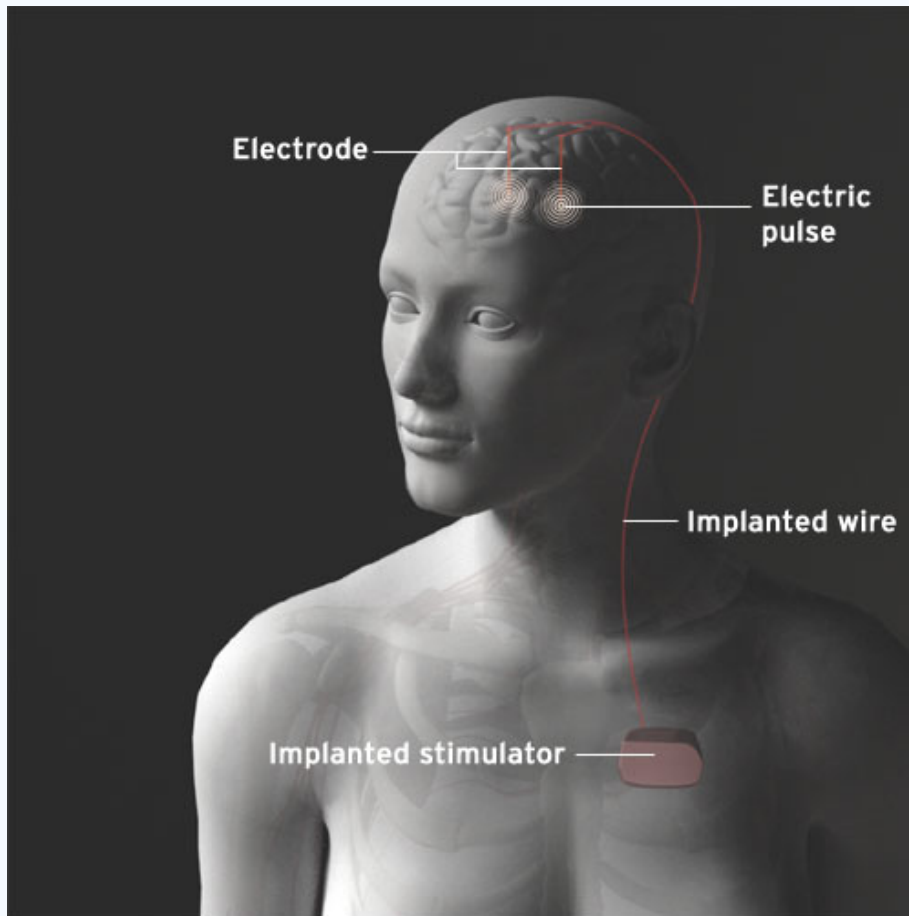
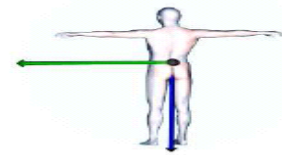
**Area: Biological Signal Processing**

**Goal: Do Neurons in Basal Ganglia Respond to Emotional Content?**



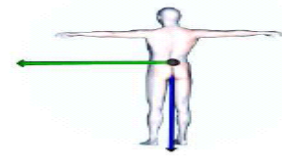
laboratory  
**Gerstner**

# DBS



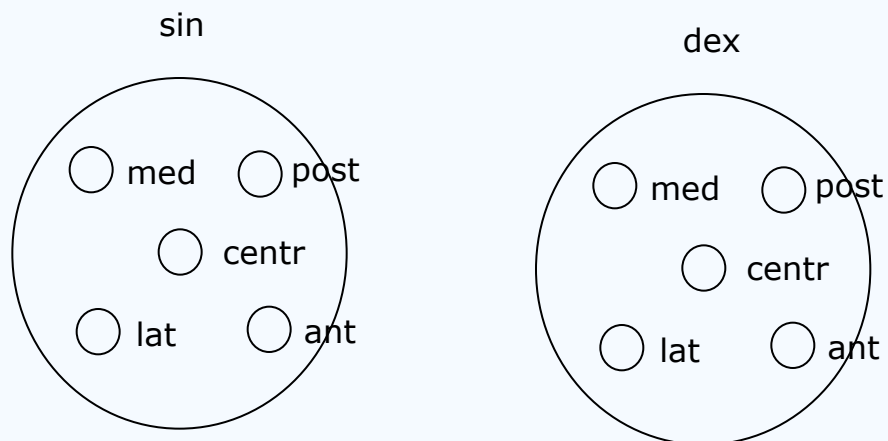
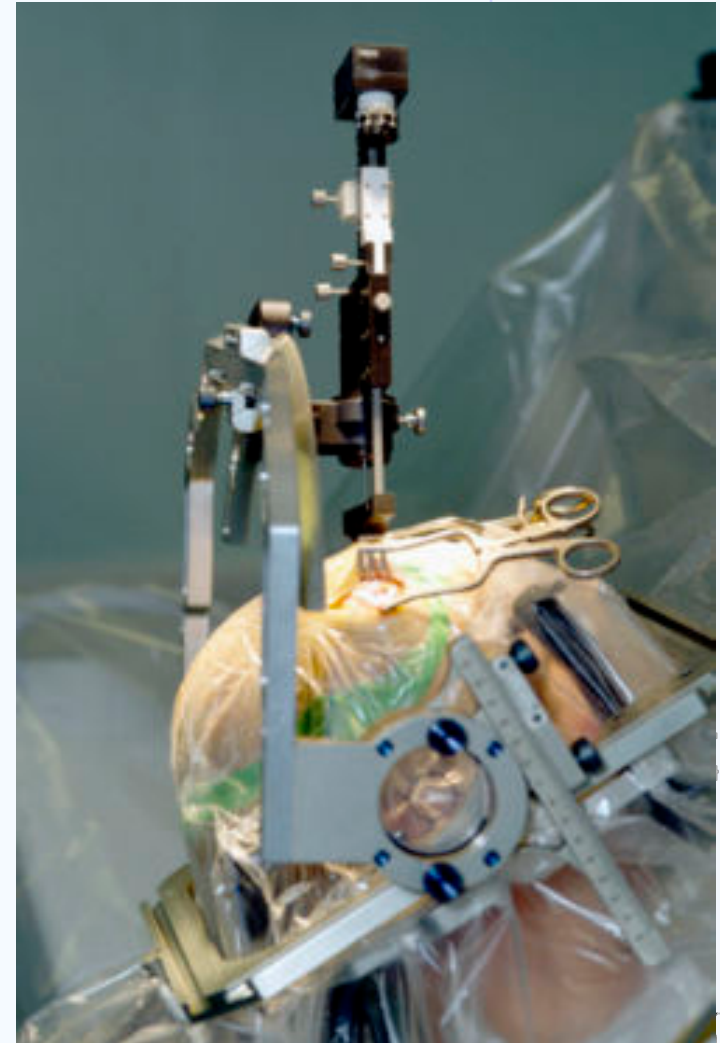
- +** Some effects are almost immediate and seem to last. Allows doctors to target brain circuits with great accuracy.
- Requires brain surgery. Few patients have received implants; little is known about how well it works.

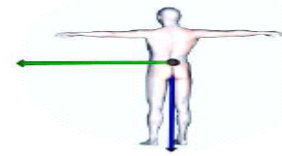




## How: Functional stereotactic neurosurgery

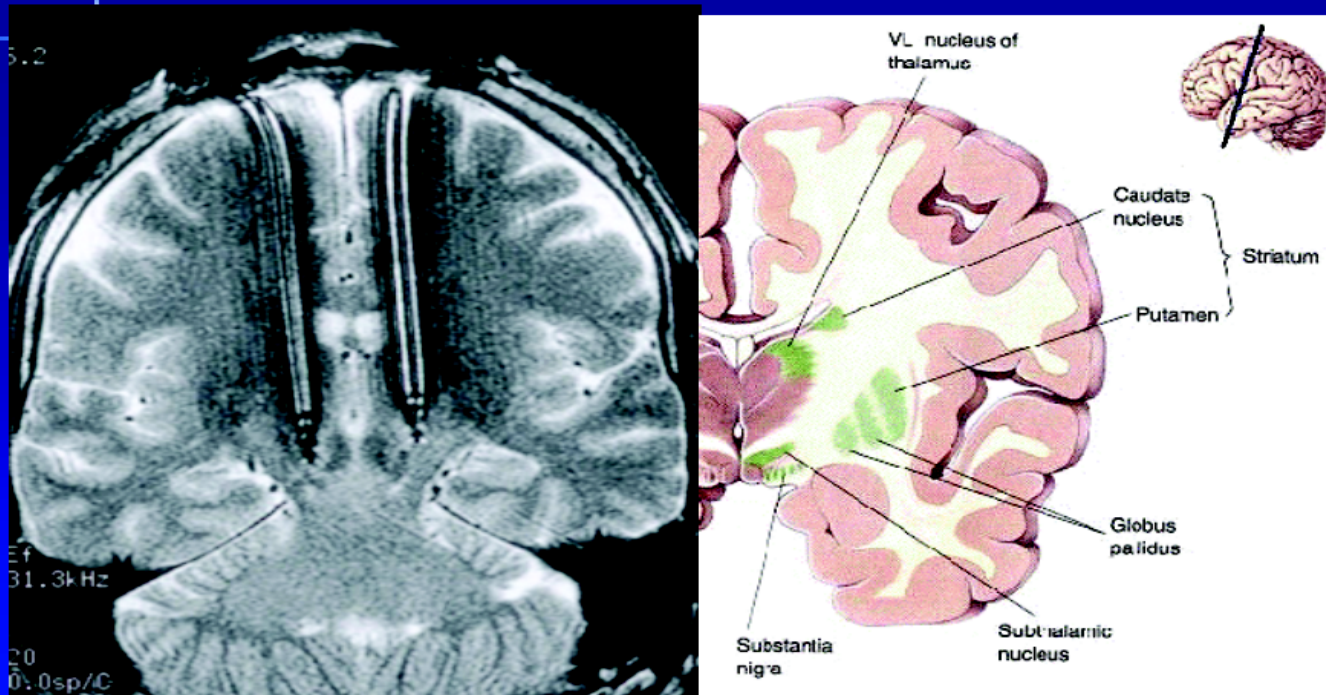
- Surgery at sites deep within the brain utilizing a stereotactic frame and stereotactic coordinates.
- Used for making a lesion or implanting a DBS electrode in thalamus or basal ganglia for treatment of movement disorders (PD, dystonia, ET), pain, etc.



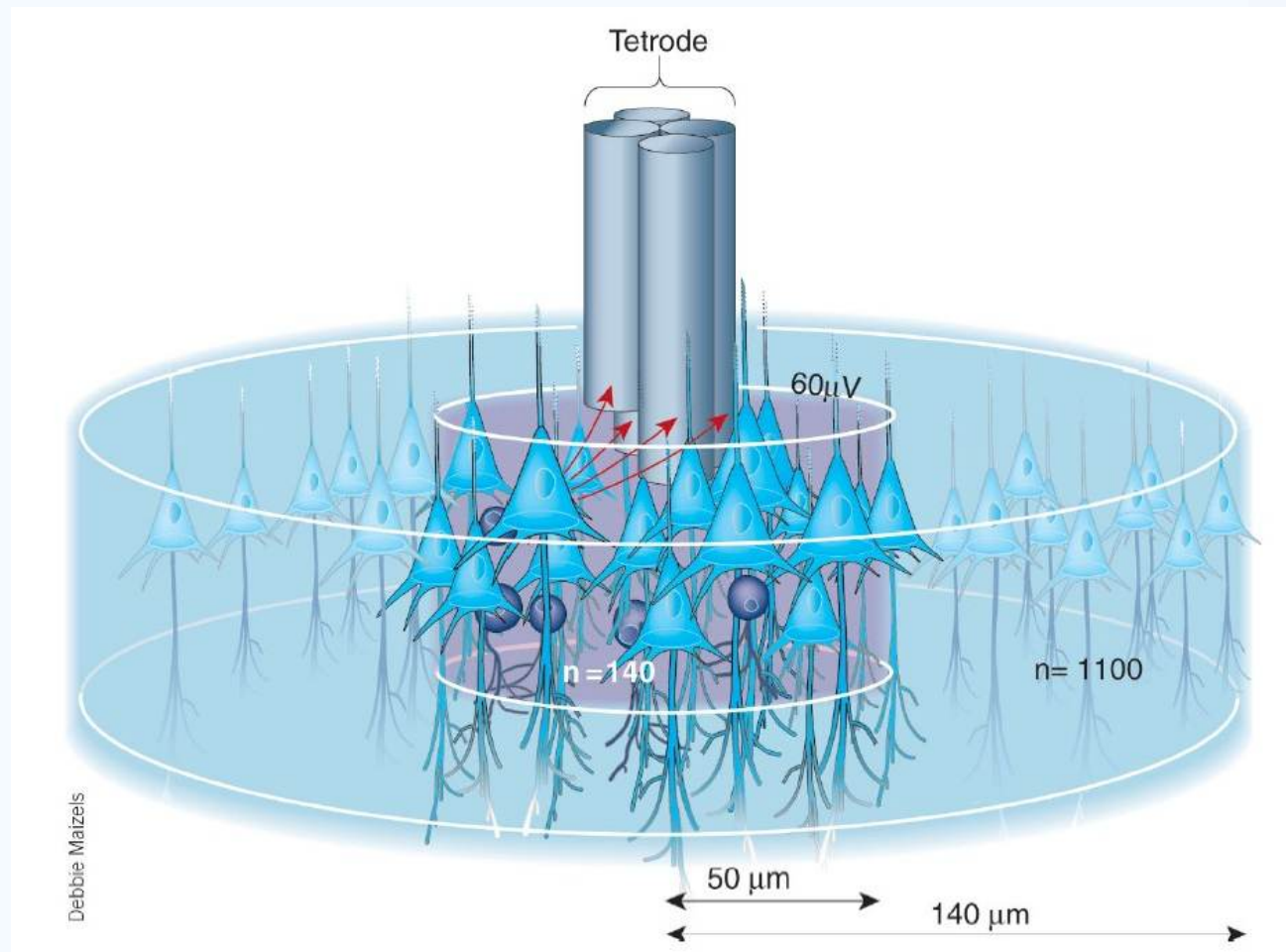
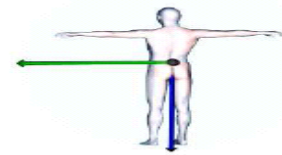


# DBS: Topography

## DBS: Topography

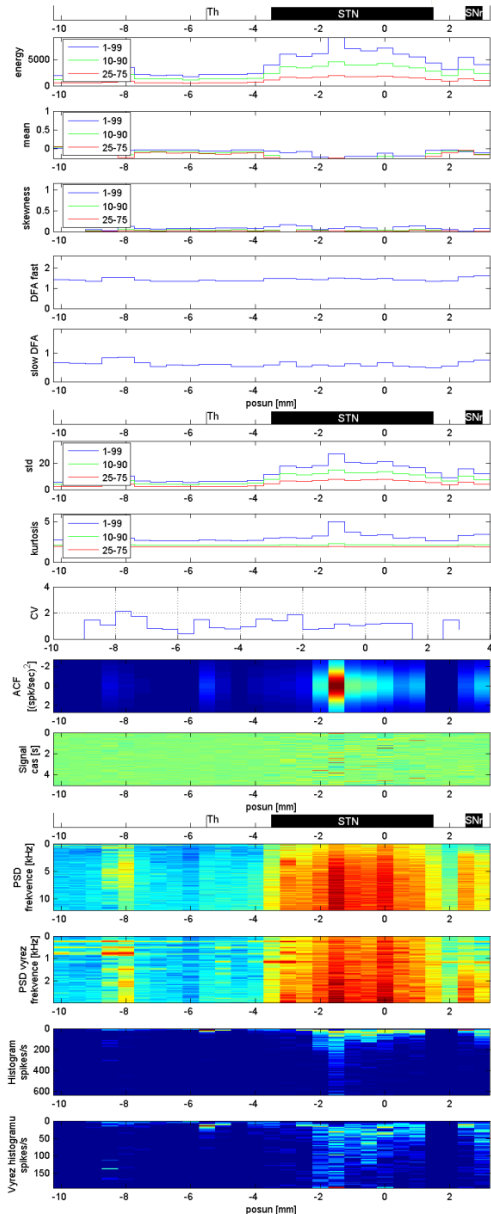
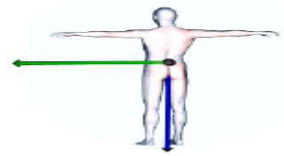


# Neuron single action potential





# Visualization of navigation – raw parameters



Micro electrode recording: DATE: 14/2/06

Kub\_J\_STNdex

Brain Target: STN dex

	Center EL	Anterior EL	Posterior EL	Medial EL	Lateral EL	DBS Lead Position
T-10	R				R	Medial
T-9				R		
T-8						
T-7					R	
T-6	R				R	
T-5	R		R			3
T-4						
T-3	R					2
T-2						
T-1			STN	STN		1
Target						
T+1		STN				0
T+2						
T+3			STN	STN?		
T+4						
T+5						
T+6						
T+7						

– Annotation  
– Surgery protocol

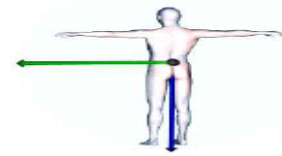
all plots  
4.0 mm post AC-PC  
12 mm lat to AC-PC  
3 mm post to HP (ACCP)



OK  
dist. lower 40° + 1.5°  
R lat  
prox. lower 34° - 6°  
post. lat

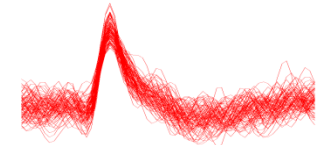
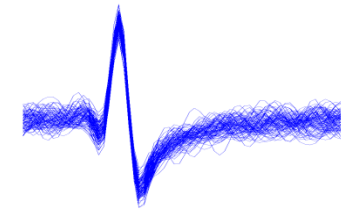
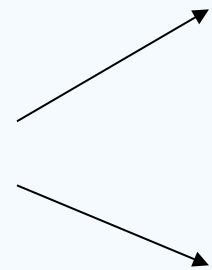
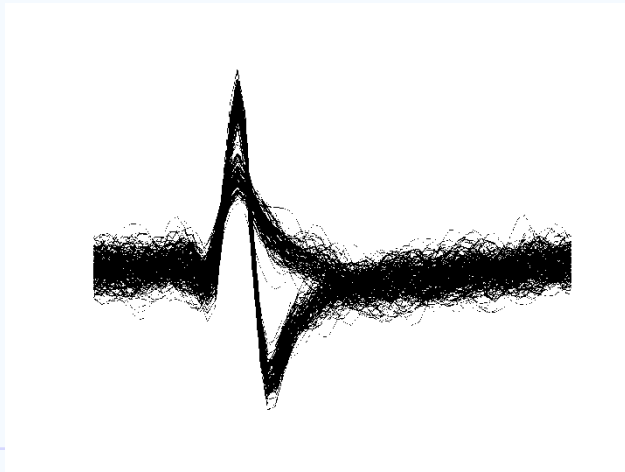
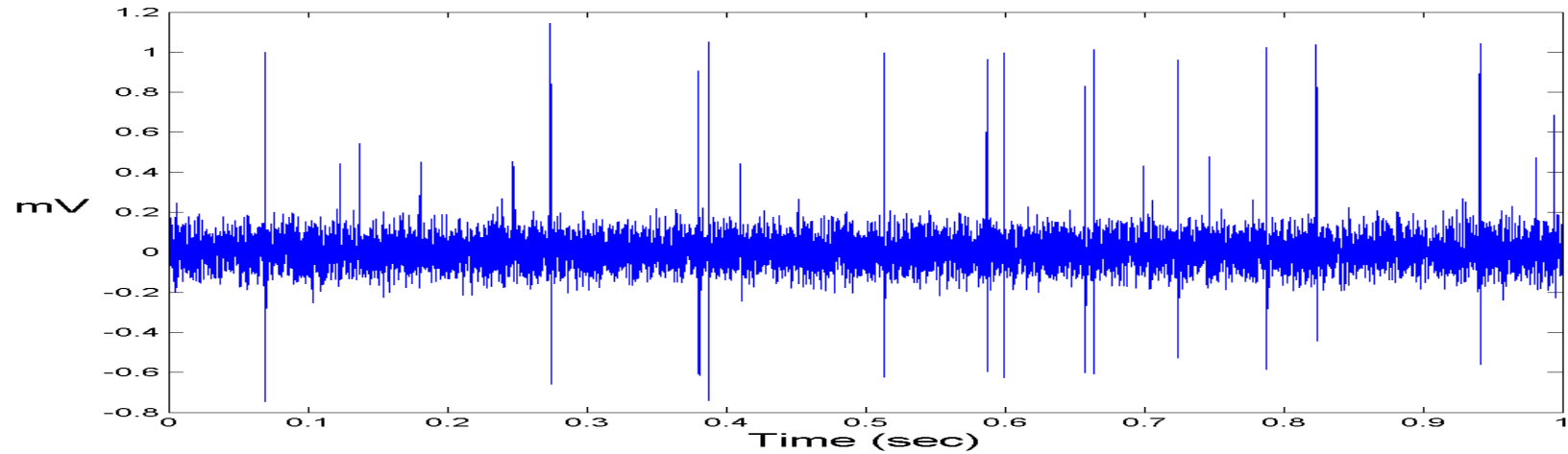


laboratory  
**Gerstner**

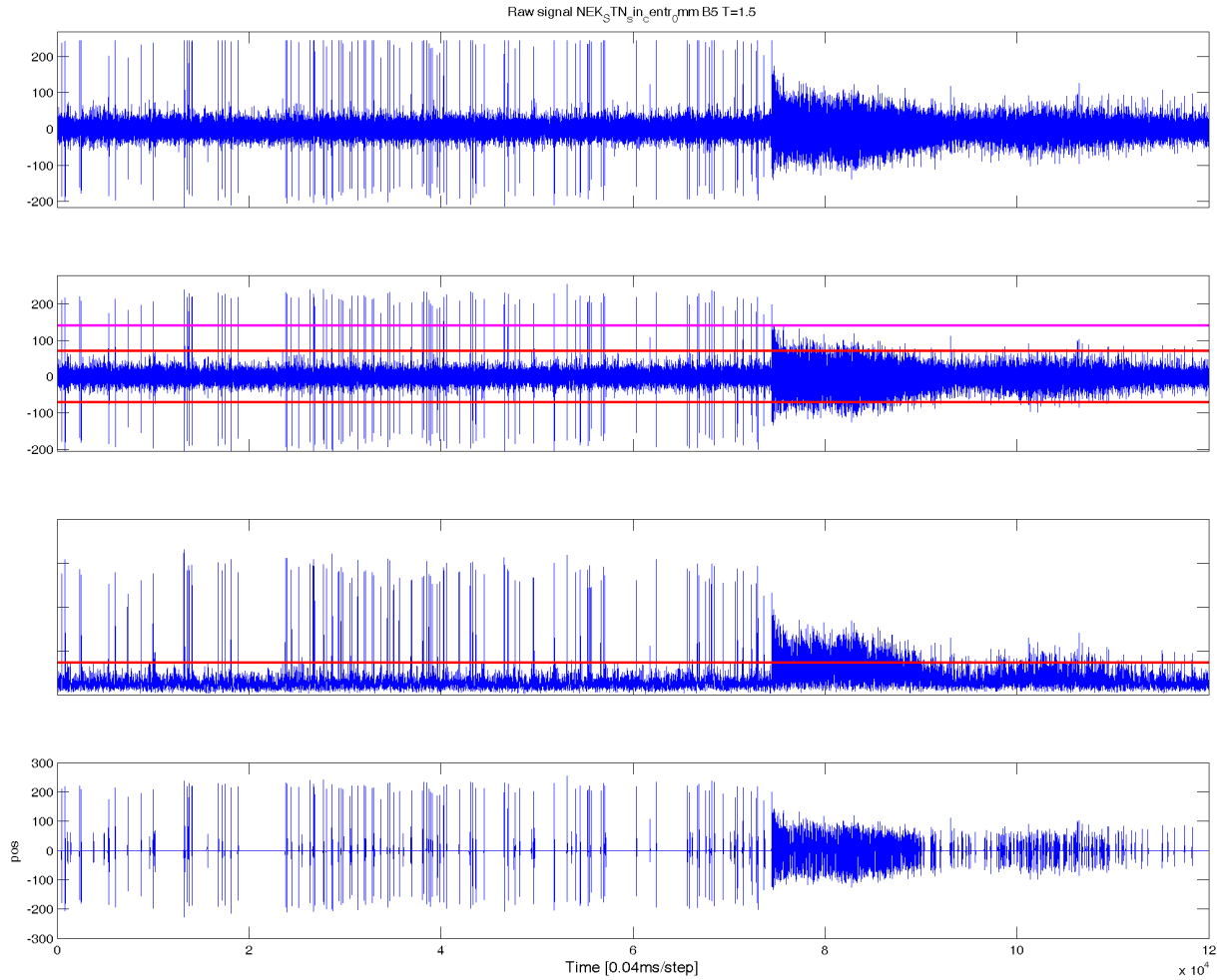
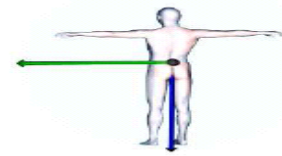


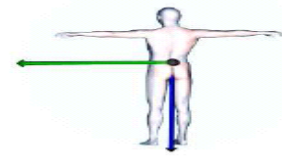
# Main Idea

- Motivation
  - Assign stimuli (picture, sound, movement) to different neurons !!!

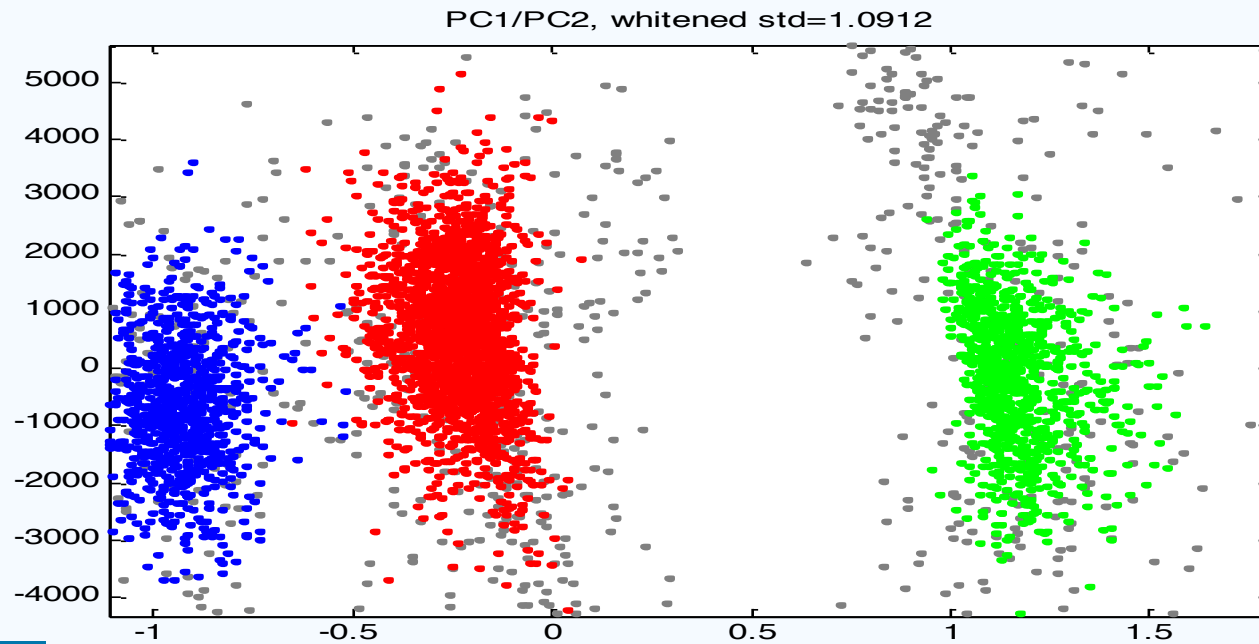
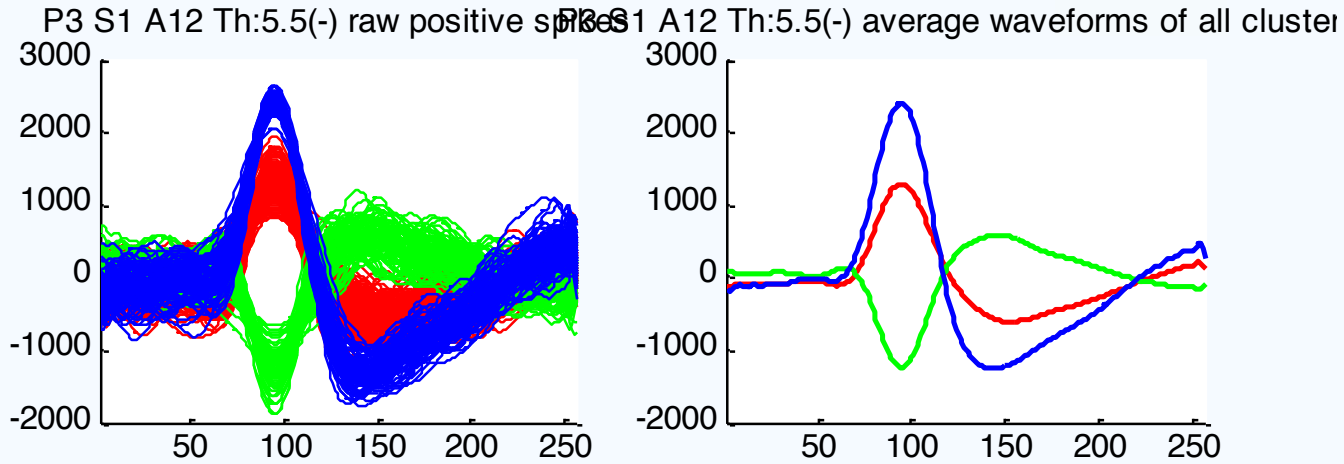


# Spike Detection

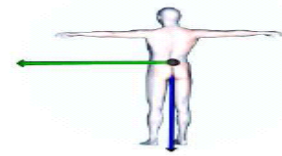




# Spike Sorting: one channel, 3 cluster, PCA projection



# Dependence UPDRS or depression?



**Stimulation**

**Neurons STN**

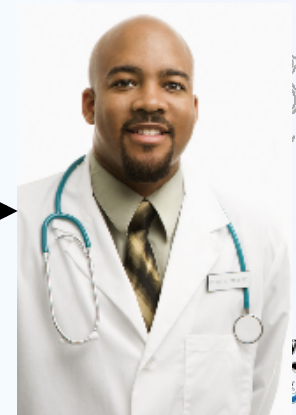


**UPDRS score**

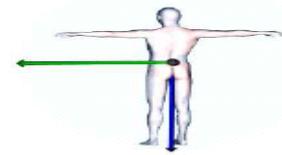
**Statistical analysis**



**Motoric examination**



# IAPS experiment



- affective visual stimulation
- a series of 24 IAPS pictures

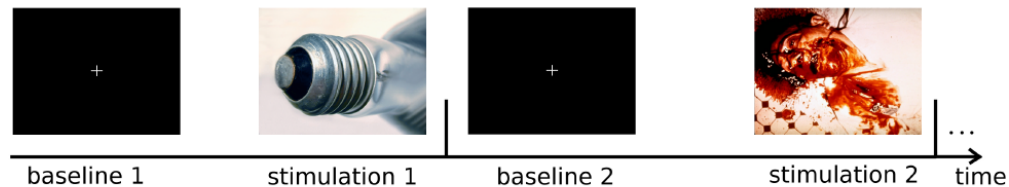


## MicroEEG Data Recording

- peroperative STN exploration
  - integral part of DBS implantation
- 5 parallel microelectrodes
- sampling at 24kHz

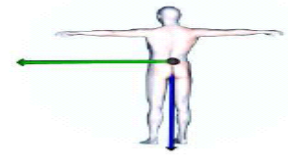


- 10 patients
- 43 recording positions
- 141 recordings (74 from STN)
- 173 minutes (89 from STN)
- 176 neurons (101 in STN)



- presentation for 2s + 2s
- recording during presentation
- pseudorandom ISIs
- pseudorandom picture emotional content
- uniqueness



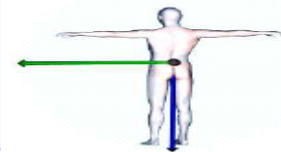


# Bipolar & Schizophrenia Analysis

**Area: Biological Signal Processing, Temporal Pattern Recognition, Multivariate Time Series Classification**

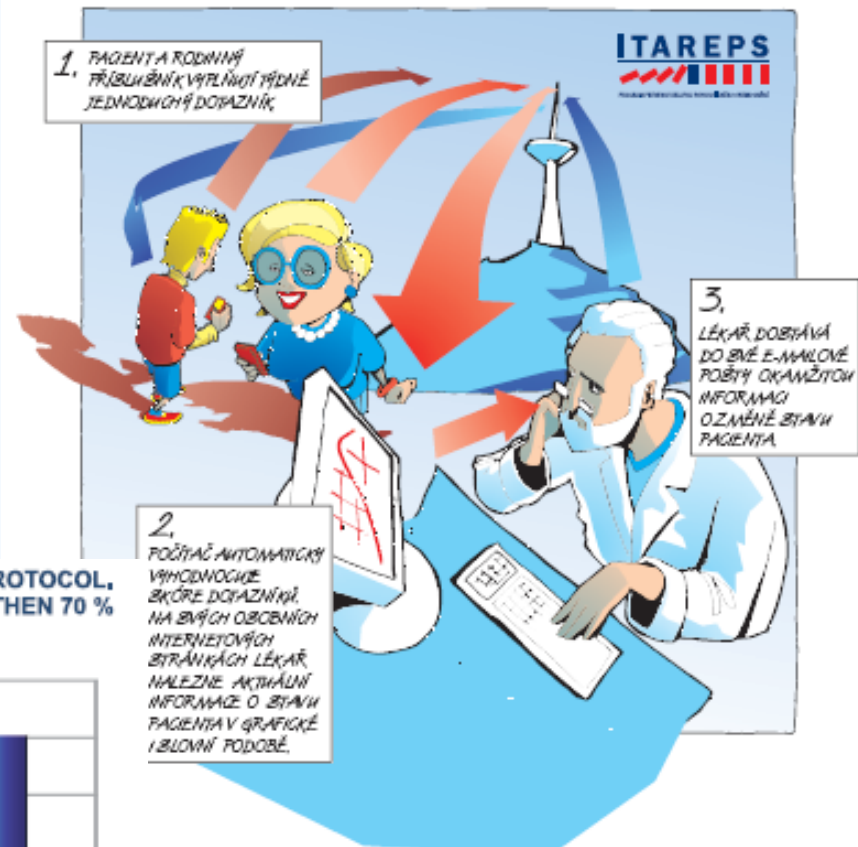
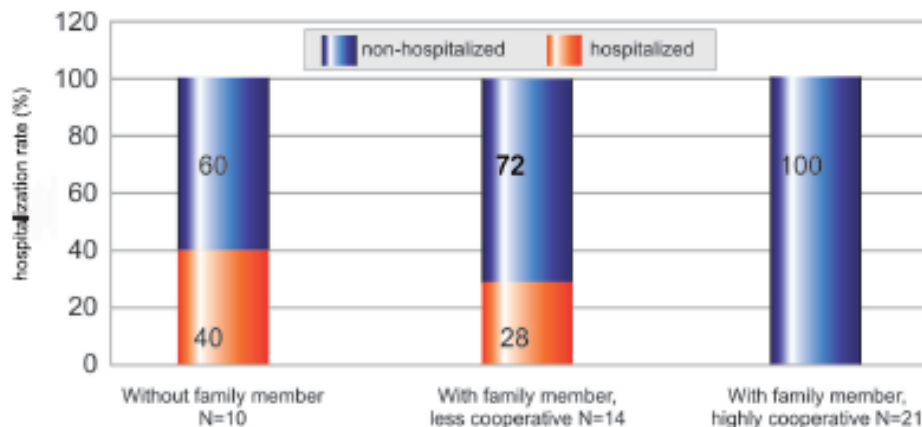
**Goal: Schizophrenia Relapse Prediction, Prediction of Mania and Depressive states**





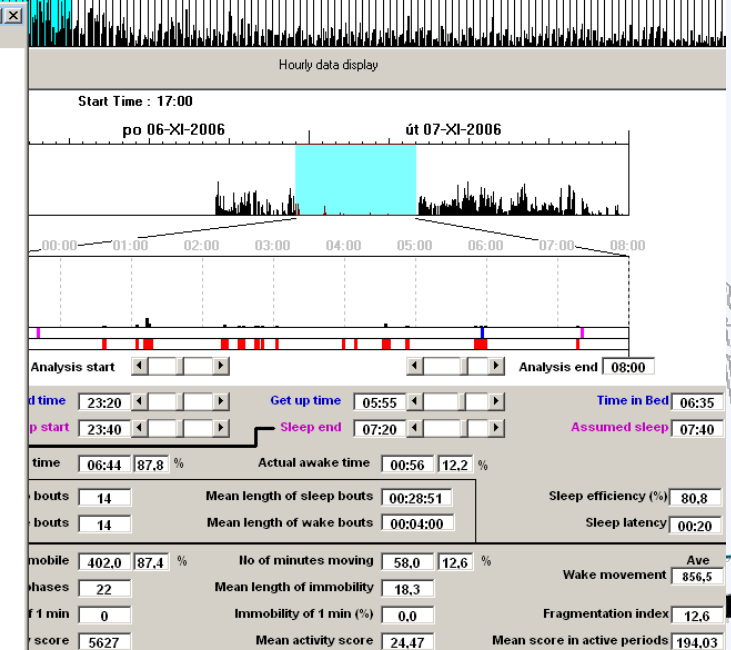
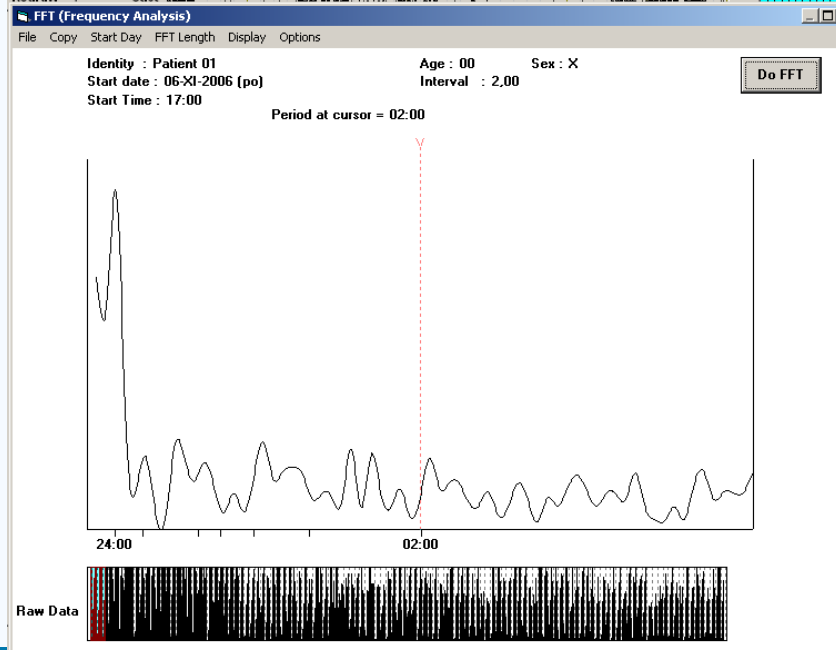
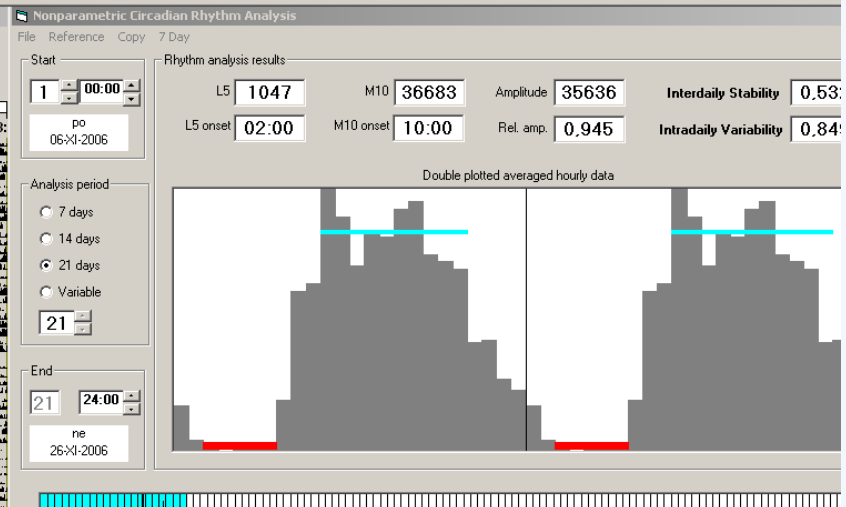
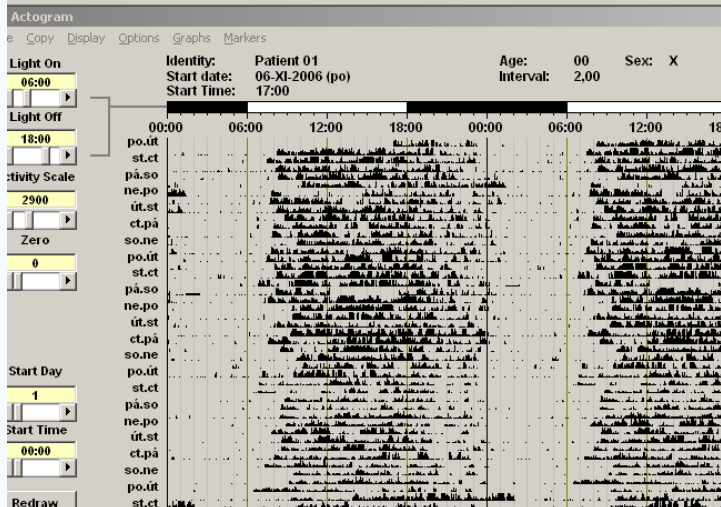
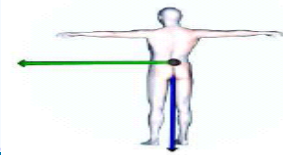
**ITAREPS**  
PROGRAM PREVENCE  
RELAPSU PSYCHOTICKÉHO  
ONEMOCNĚNÍ

**Fig. 1: HOSPITALIZATION RATE AND ADHERENCE TO THE ITAREPS PROTOCOL, CUT OFF POINT OF COOPERATIVENESS DEFINED AS MORE OR LESS THEN 70 % OF REQUIRED EWSQ QUESTIONNAIRES RETURNED**

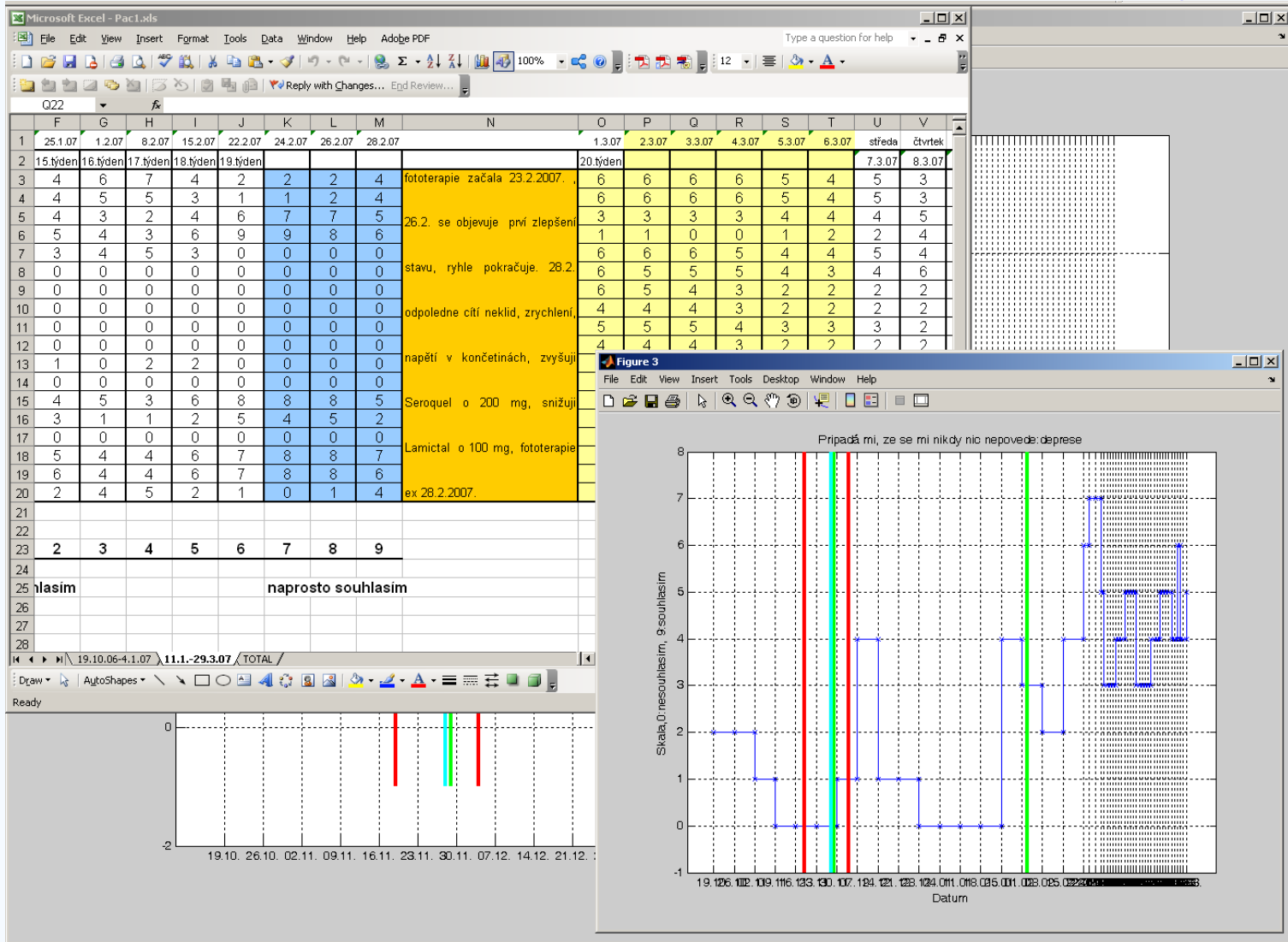
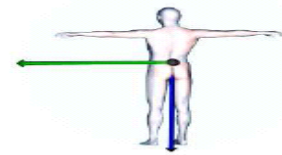




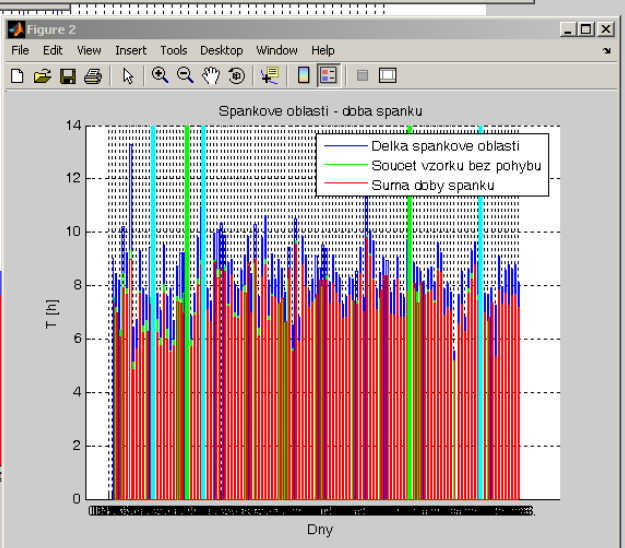
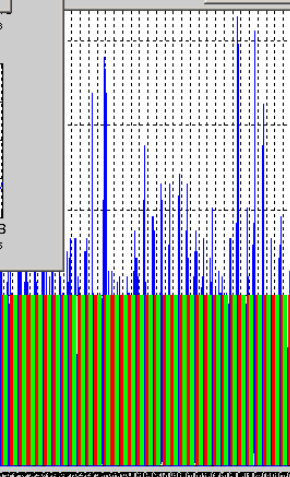
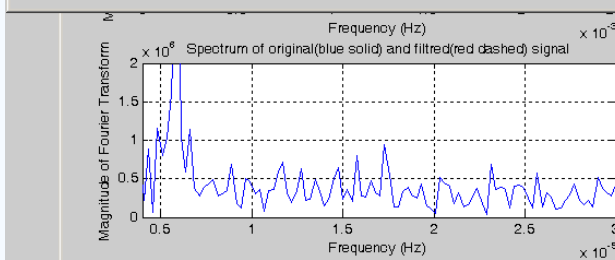
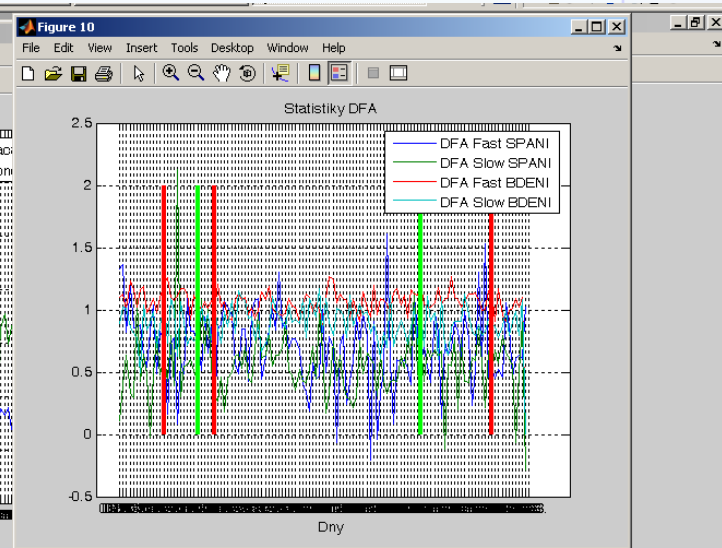
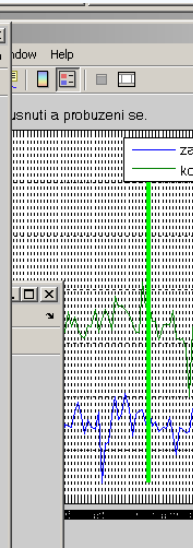
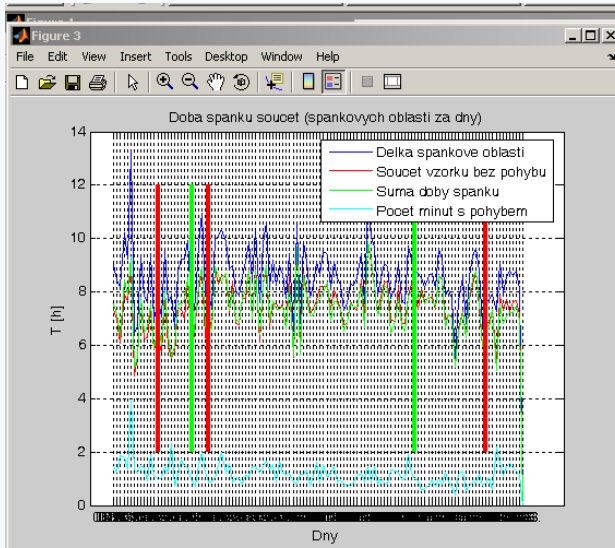
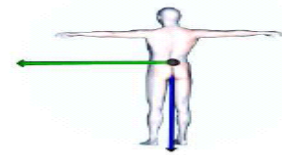
# Sleep Analysis

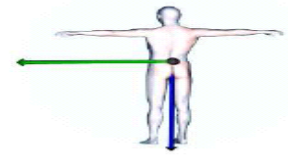


# Questionnaires



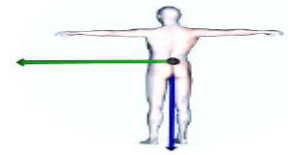
# Sleep analysis





# Ambient Assisted Living Systems





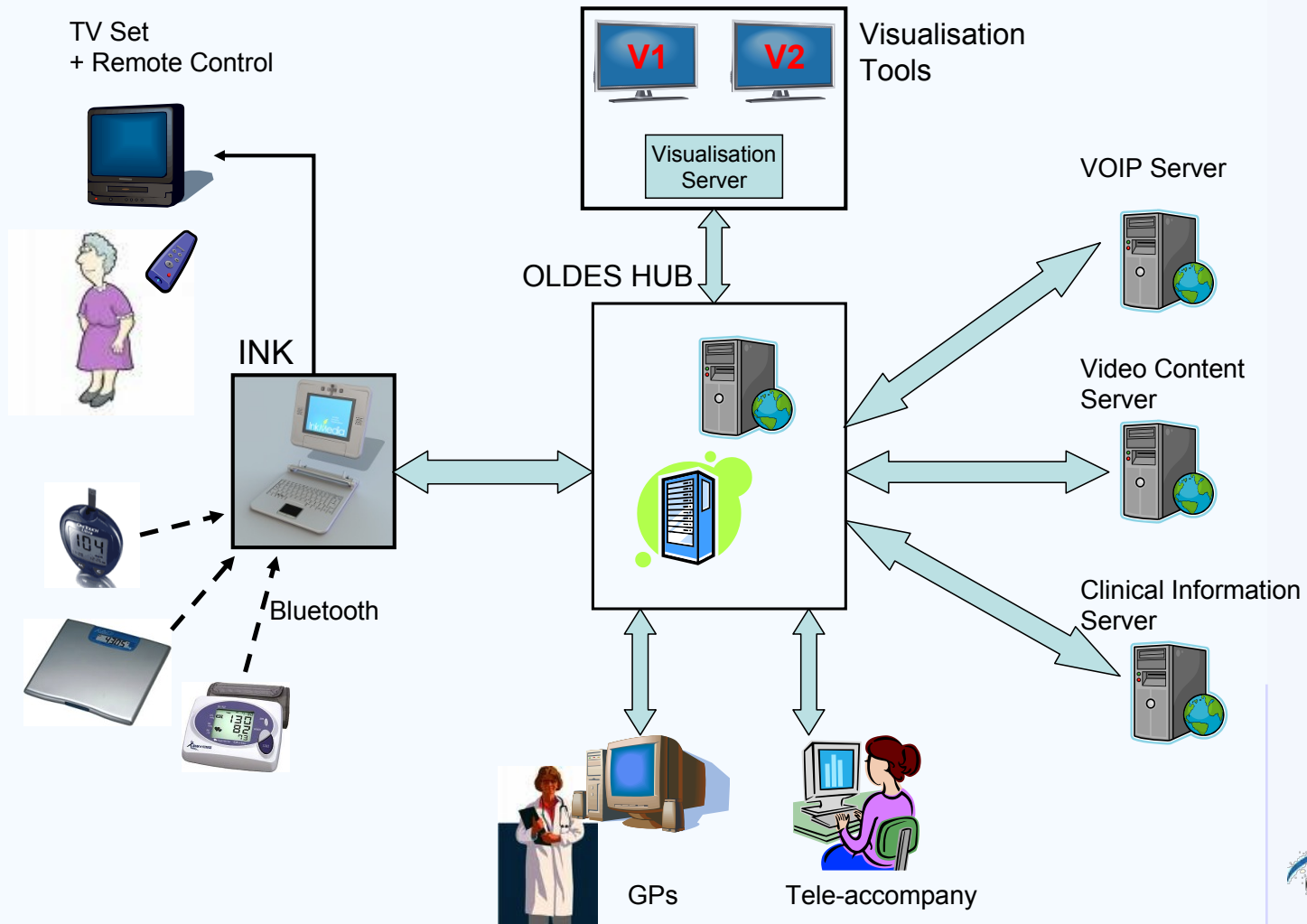
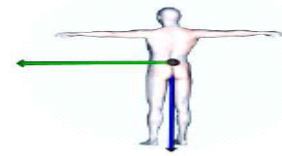
# Example of telemedicine system **OLDES** (Older People's e-services at home)

**Area: Asistive Ambient Living, Applied Gerontology**

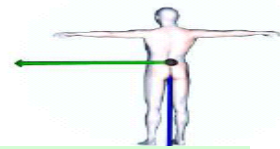
**Goal: Diabete project: Glycemia prediction,  
User Interface Development**



# Demonstrator Architecture



# Hardware Layer



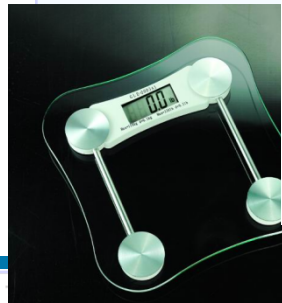
Glucose monitoring



Hear Rate



Blood Pressure



Personal Scales



Food Scales



Caloric Expenditure

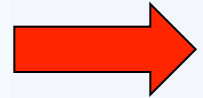
Bluetooth  
Zigbee  
USB  
Serial

Mobile solution  
i) bluetooth  
ii) GPRS module

Datalogger



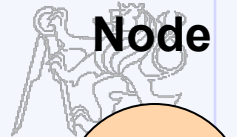
Alarms



INK Local node



Central Node



CN

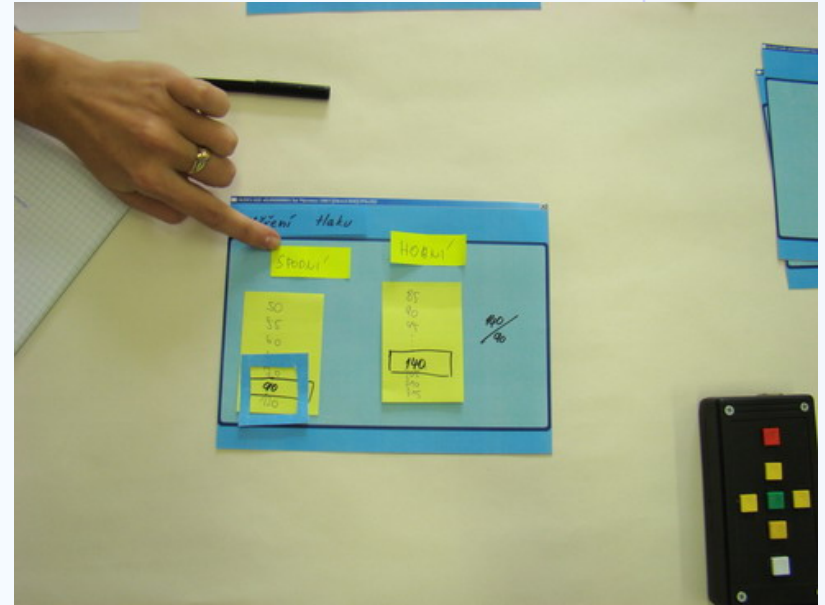
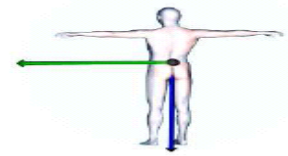


ink



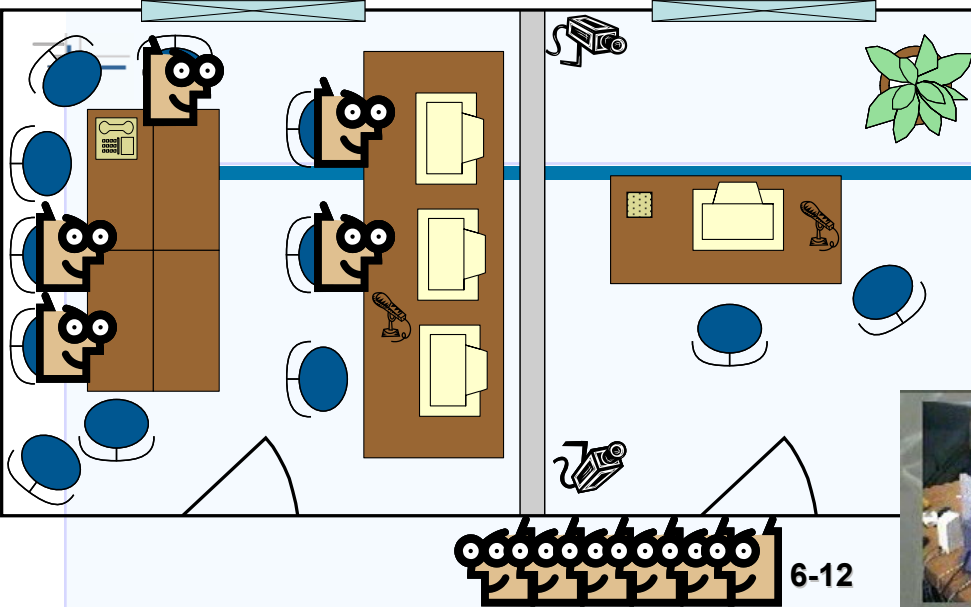
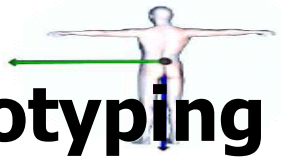


# Paper prototyping



IST Programme

# Software prototyping



OLDES GUI Prototype v0.1 CTU/UK 9.10.2007

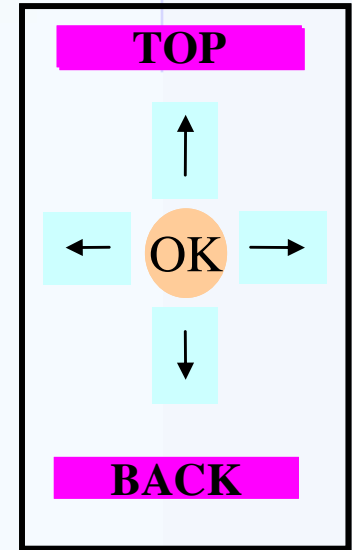
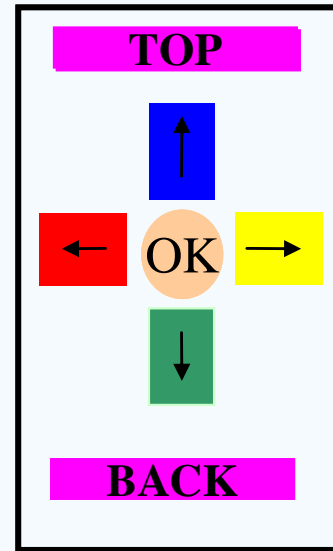
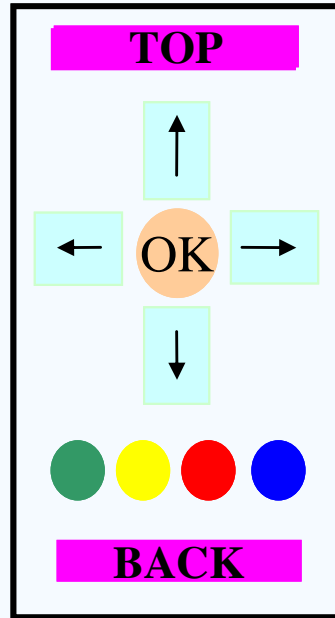
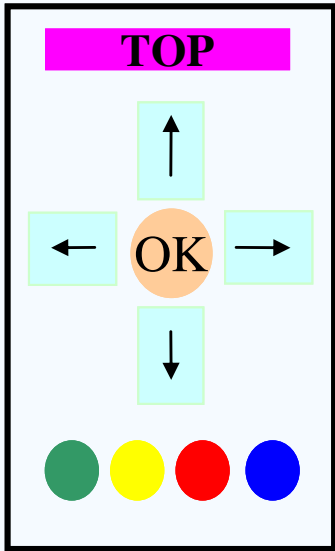
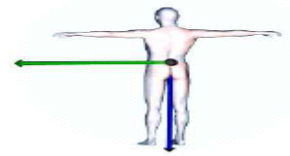
Home

Glycemia ✓ 5.9	Pressure ✓ 133/77	Weight 60 kg
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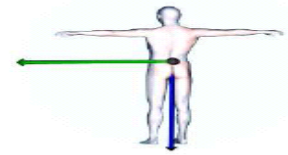
Food menu

Weight  
57

# Tangible User Interface Design Evolution



# GUI Example



((oides)) OLDES Web GUI Prototype 0.1

Thu 19.6.2008

09:52:35

## Home

Call

News and Info

My Diary

I'm interested in...

Let's talk about...

Food menu

Nejnavštěvovanější Jak začít Přehled zpráv

((oides)) OLDES Web GUI Prototype 0.1

Thu 19.6.2008

09:54:47

## Contact List

Adam

Petr

Maria

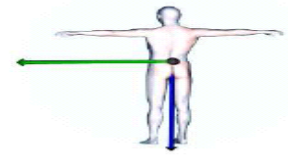
Calling..

Calling Petr

Cancel

Back

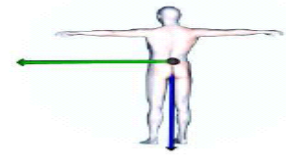
# Giraffe project



- Giraffe project and then spin-off
- Simple assistive robot
- 7000 Euros
- Navigation using mouse and fisheye camera
- Old person sees your face projected via webcam
- 500 Euros lease per month
- Nice video here:
  - <http://www.giraff.org/learnMore.html>



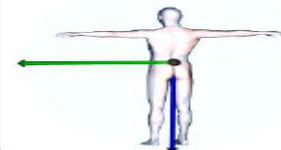
# HeerMeFeelMe



- Finland example of NFC technology for pills reminding
- HMFM explores the possibilities for improving the quality of life by providing mobile service access for the visually impaired older adults using services related to (a) medication and medicine related information and services, and (b) health monitoring and diet information.
- Video: <http://www.youtube.com/watch?v=ZBTJPD2iKhM>
- **VERY INTERESTING PAGE:** <http://mocs.vtt.fi/>



# Mobile Applications



– mobile-medical-group.com

