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Universidad de Oviedo

IEEE

2018 ANNUAL MEETING OF THE SPAIN IEEE IMS CHAPTER,
University of Oviedo, Spain, January 19, 2018

Smart Sensors and Tailored Environments for Neuro-Motor Rehabilitation Monitoring in IoT Era

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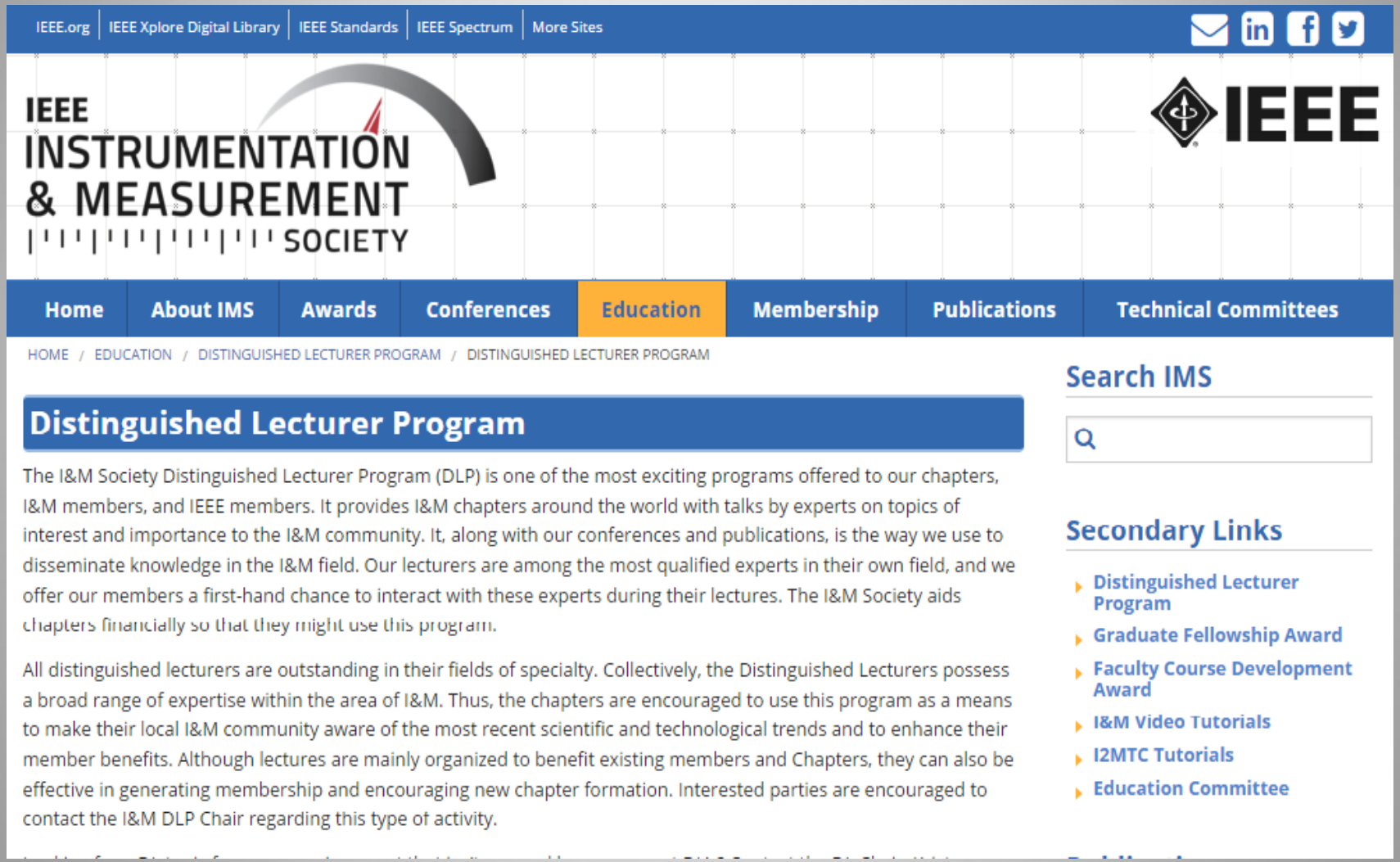


IEEE IMS DL Program

Now: Active 9 IEEE IMS DL

– **Kristen Donnell**

AdCom (2016-2019);

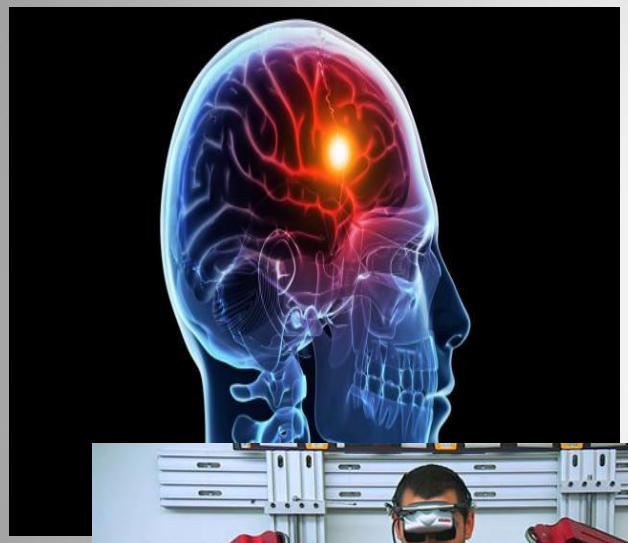
– Distinguished Lecturer Program Chair

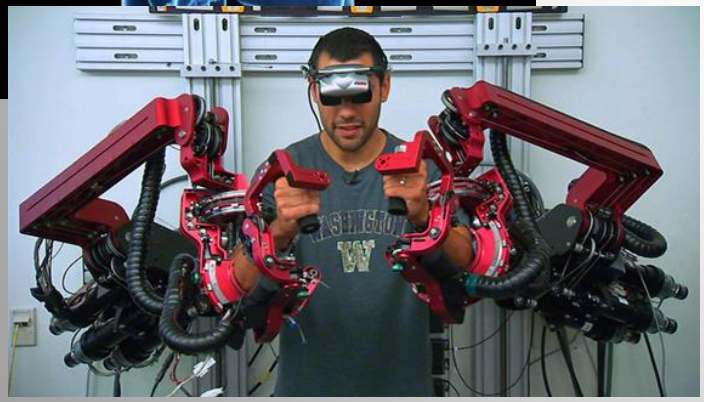
- http://ieee-ims.org/education/distinguished-lecturers-program

Outline

- Physical Therapy Today : *Facts, Motivation, Technologies and Challenges*
- Objects & Technologies in Tailored Environments:
- Instrumented Walking Aids
- Smart Insole
- Serious Games for Physical Therapy
- Objective Evaluation of Physiotherapy sessions by Thermography
- Conclusions

Physical Therapy
Stroke *Facts*





The number stroke patients recovering in rehabilitation clinics increase.

15 million people suffer stroke worldwide each year (WHO).

5 million having to work for their motor and cognitive recovery

- 5 million die
- 5 million are permanently disabled
- *What about solutions ?*

Physical Therapy

Cerebral Palsy *Facts*

Affects movement and posture

17 million people worldwide

2 in 1000 Europeans suffer this motor disorder

Especially applied for children and young people

What about solutions ?

Physical Therapy

Reality and Challenges

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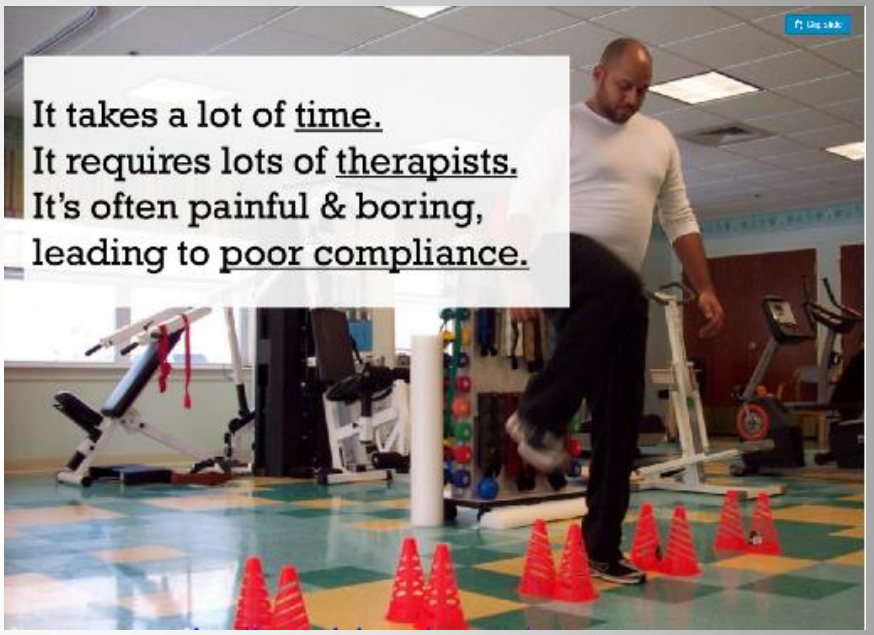
Today



Tomorrow

- Provide objective evaluation of the patient performances
- Increase the patient motivation through appropriate feedback
- Reduce the rehabilitation period

→ What about methods and systems?

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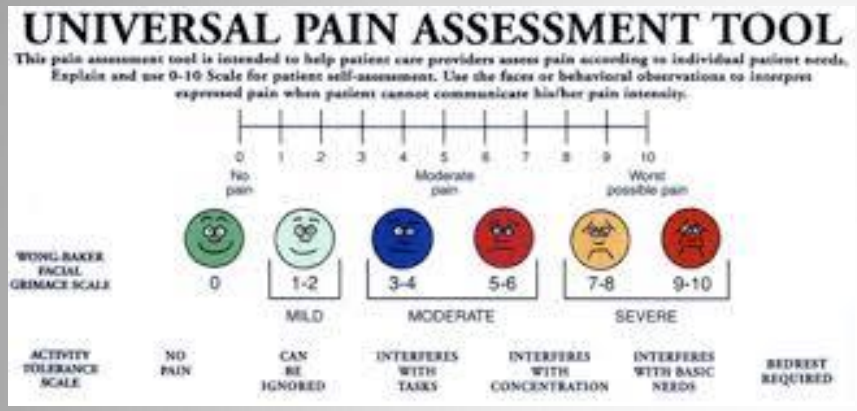
Physical Therapy

Today evaluation



Subjective evaluation based on scales, manually data record

Basic tools no data record, no patient feedback, no IoT

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Physical Therapy

Today and Tomorrow Clinics

– Exclusively Usage of Mechanical Devices by the physiotherapists in Regular Clinics

- No Feedback for user or physiotherapists
- No Data Records or/end Internet Connectivity

How about IoT compatibility for tomorrow?

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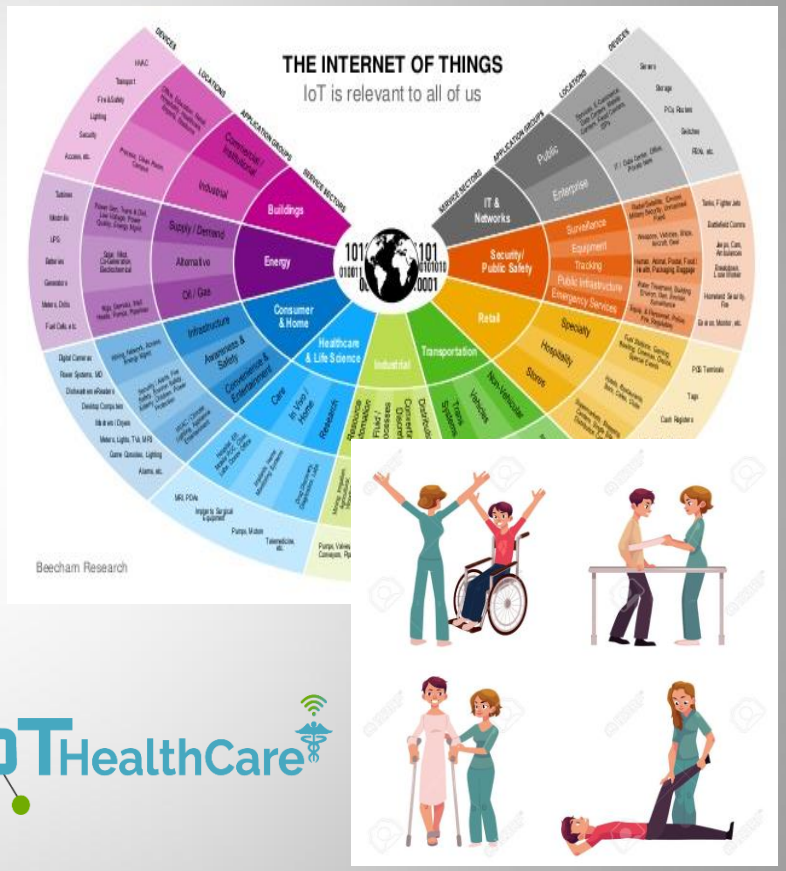
Physical Therapy

Technologies for Today and Tomorrow

- Develop smart sensing device with IoT compatibility,
- Develop appropriate training plan and adapted environment

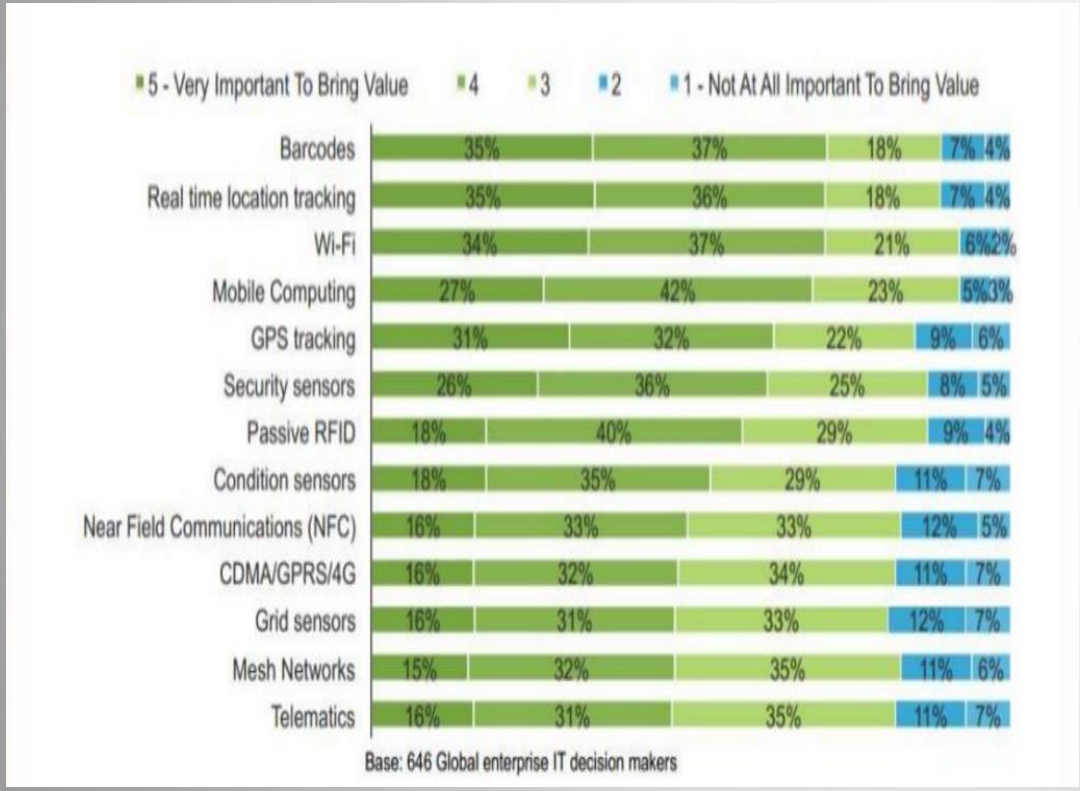
  VR or AR are coming
- Perform data record for each session
- Develop and calculate metrics that characterize the physical training effectiveness



IoT HealthCare

26 billion devices connected to the Internet by the year 2020→
some 10th of millions related healthcare assessment (Forbes)
What about IoT Today and Tomorrow Technologies?

IoT technologies
for IoT Healthcare



- RFID
- IEEE802.11, IEEE802.15.1, IEEE802.15.4
- 3G UMTS, 4G LTE, 5G
- Barcode e QR code
- Sensors and Smart sensors
- Mobile Devices
- Cloud Computing

What about IoT Technologies in Physical Rehabilitation Equipment?

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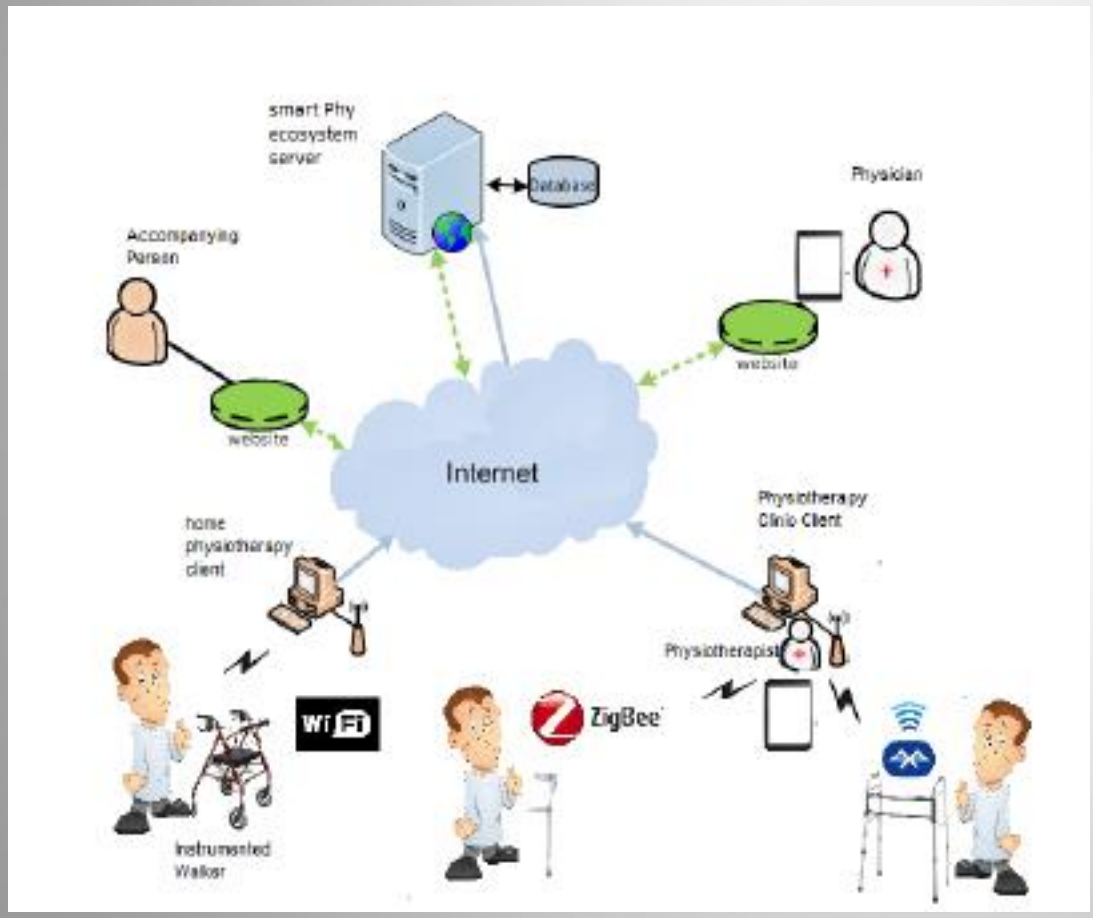
Smart Physiotherapy

Walking Aids Network for Gait Rehabilitation

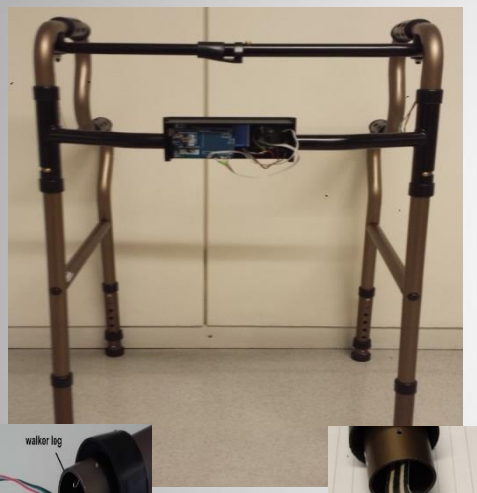


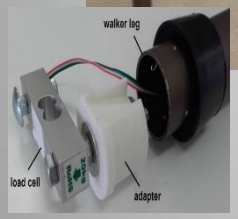
- Smart walking aids: walkers and crutches provide dynamic and kinematic information during the rehabilitation process

- IoT compatibility *(smart phone, tablet) or client PC, Wi-Fi Yun Shield)*

Walking Aids Net Nodes

smart walker prototypes

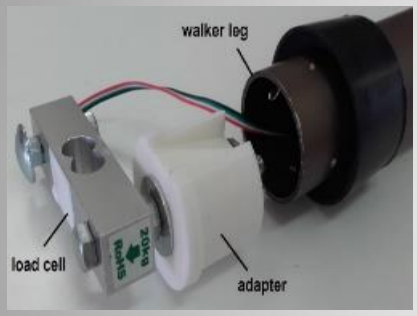


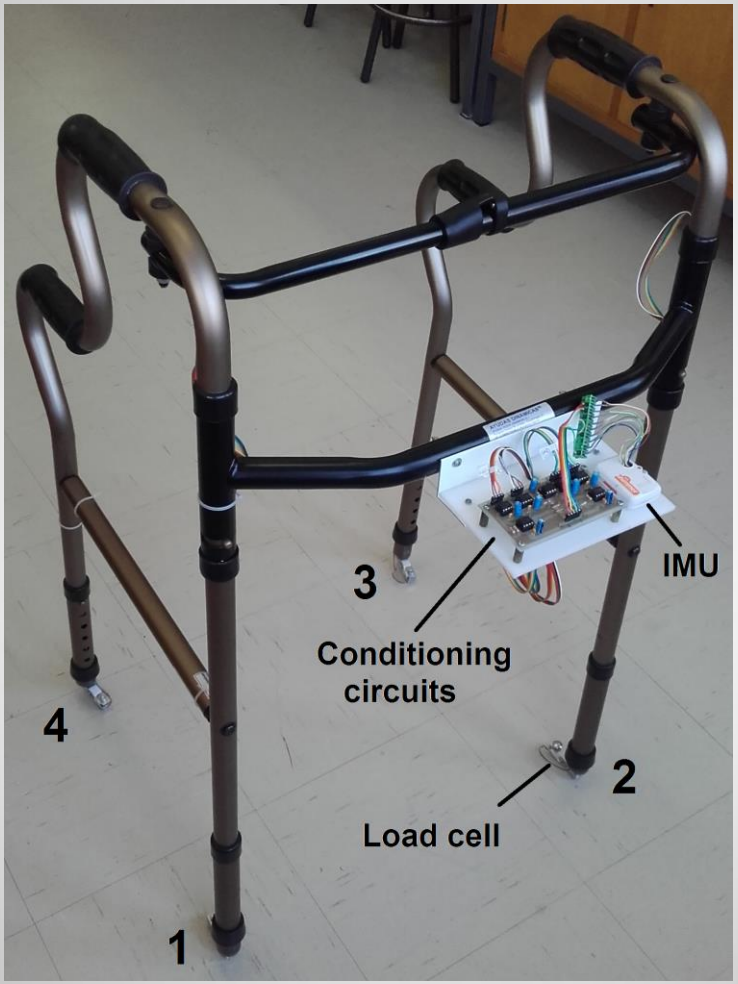


standardW 2wheelsW 4wheelsW

O.Postolache et. al., IEEE, ICST 2011, NZ, O. Postolache et. Al., IEEE MeMeA 2015, Turin, Italy
O. Postolache IEEE EHB 2015, Iasi, Romania

Walking Aids Net Nodes
standardW prototype

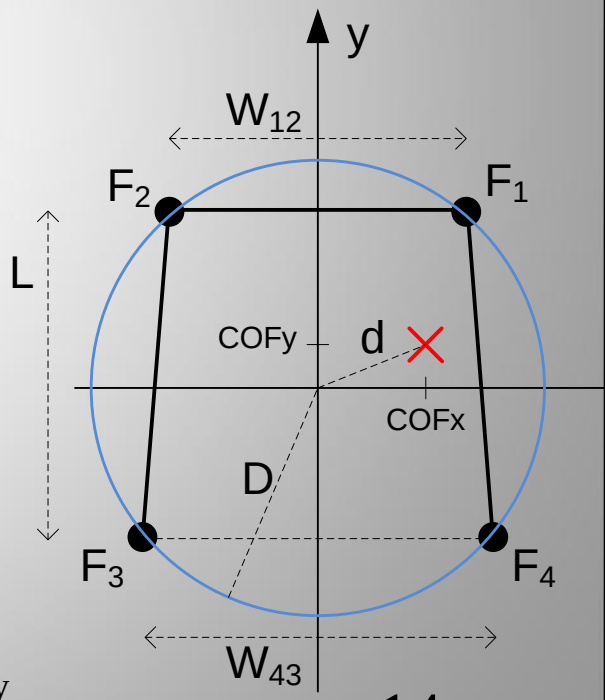




» Risk index (un)balance:

$$I_1(\%) = 100 \times \frac{d}{D} \times \alpha$$

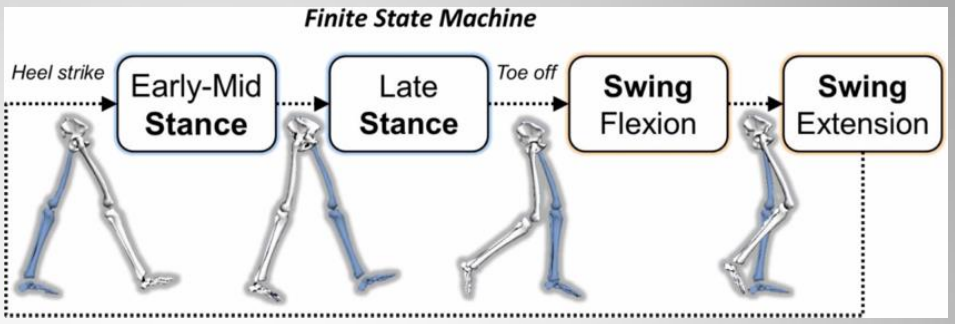
α: weighting factor



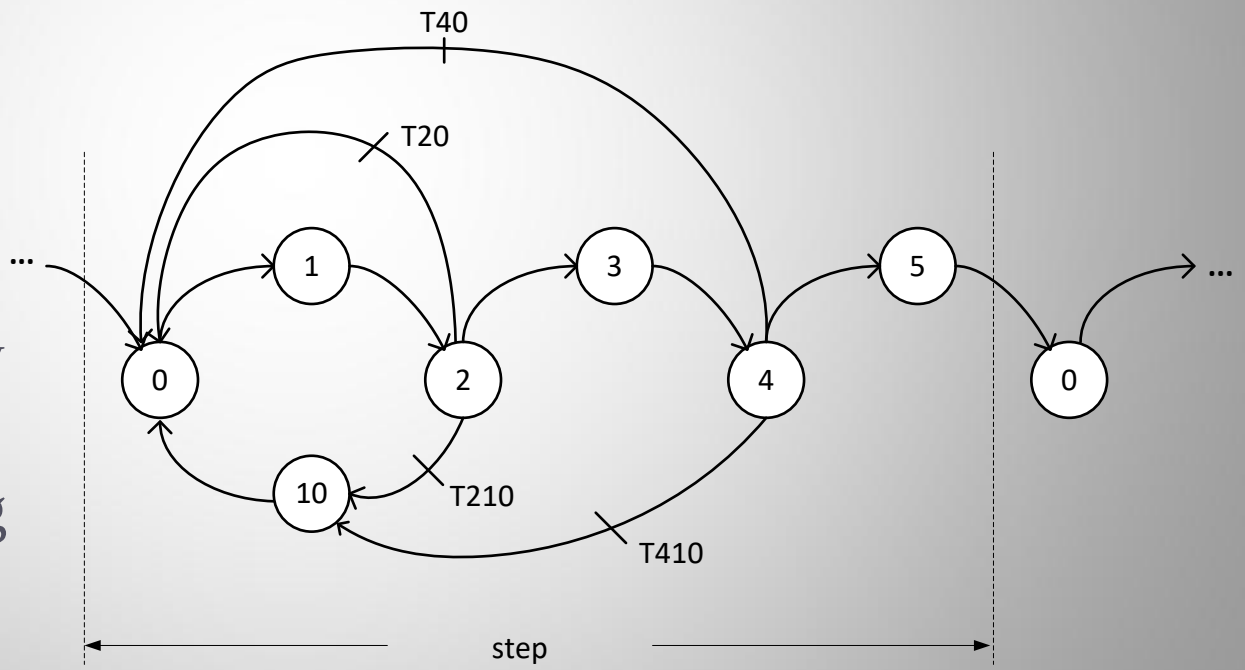
COF: Center of Forces

Smart Walker

state machine for step classification



0: Waiting for the walker to lift off;
1: Walker is flying;
2: Waiting for the injured foot to move forward;
3: Injured foot is moving forward;
4: Waiting for the healthy foot to move forward;
5: Healthy foot is moving forward.



classified "correct" step →if the user completes all states from 0 to 5
The incoordination index I2 is calculated.

$$I_2(\%) = 100 \times \frac{B}{N}$$

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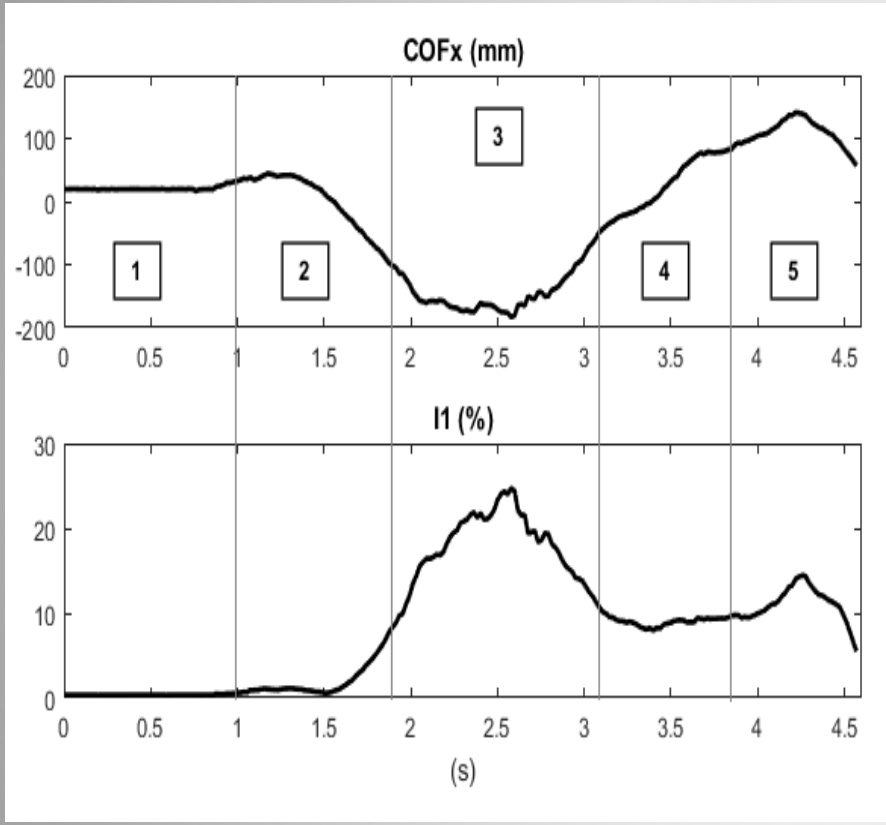
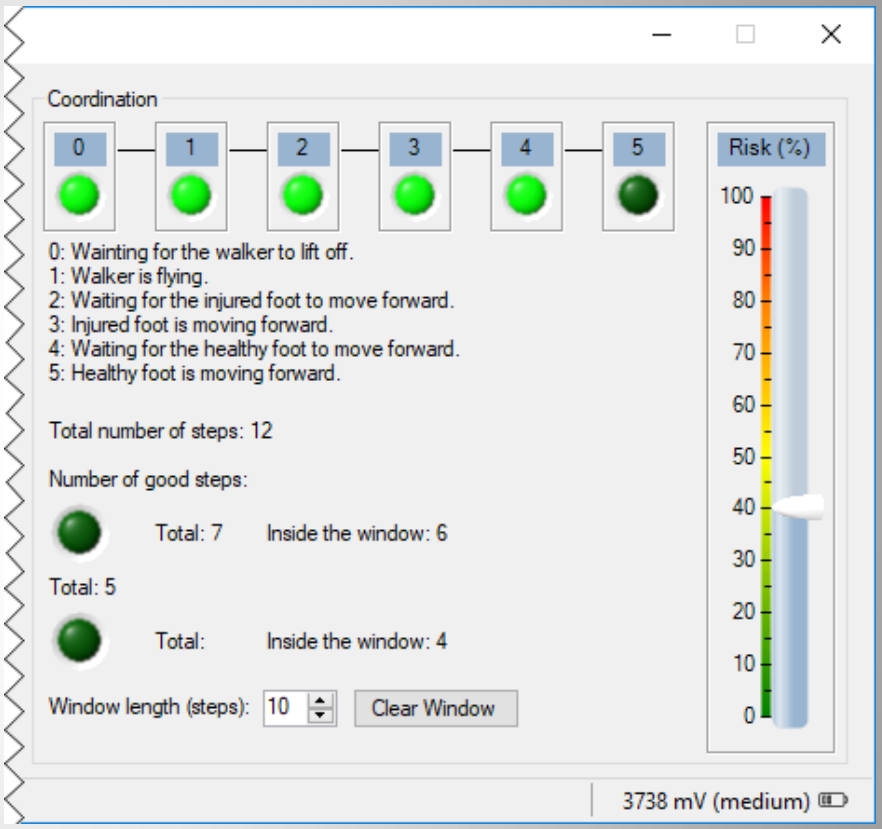
Smart Walker

indexes and state machine evolution



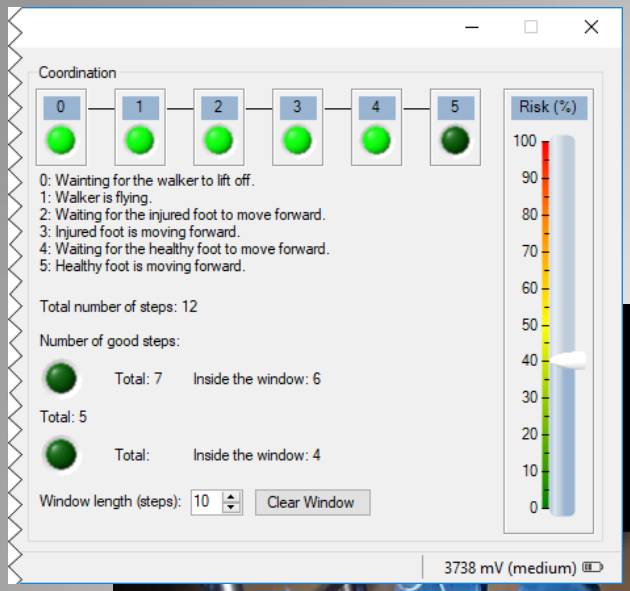


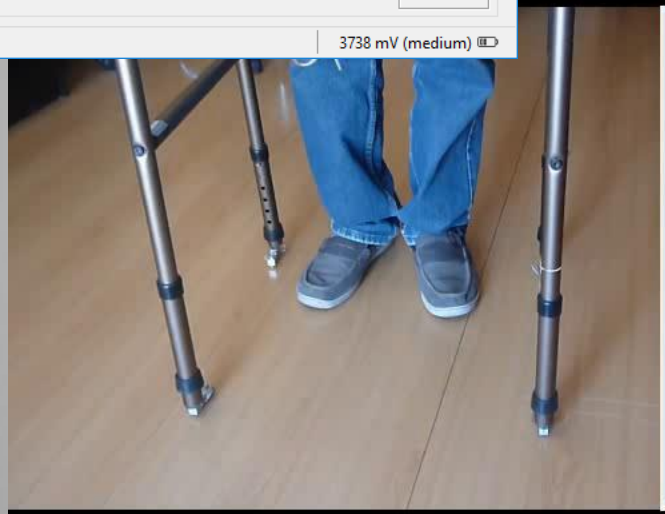
(the squared boxes numbered 0 to 5 indicate gait states)

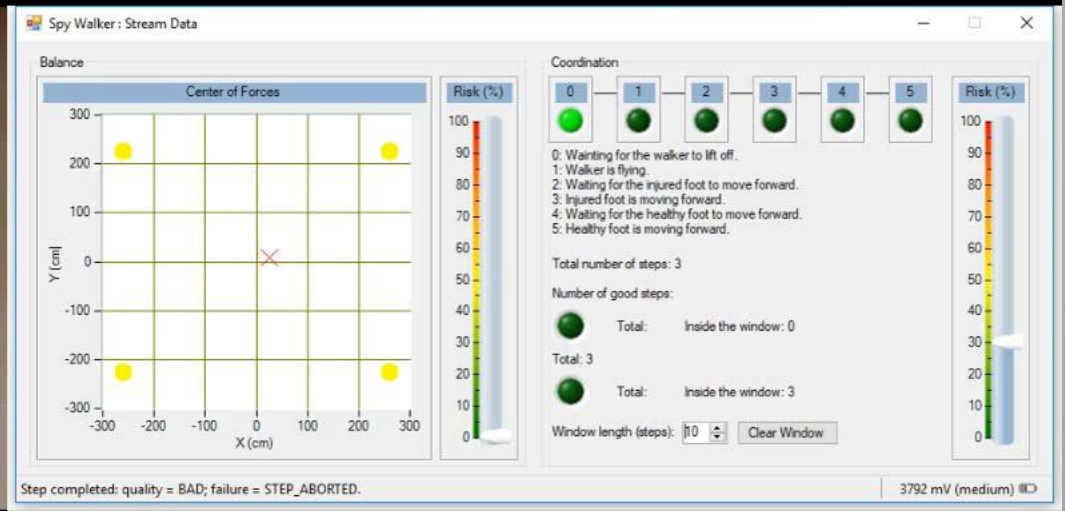
classified "correct" step →if the user completes all states from 0 to 5.

Smart Walker

indexes and state machine evolution

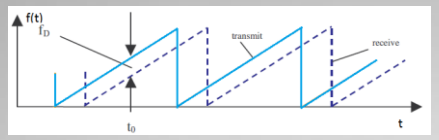


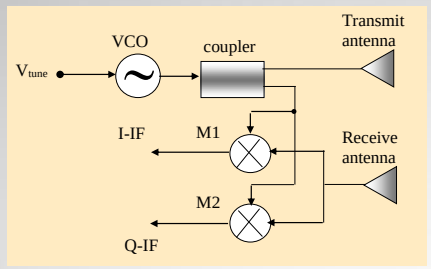




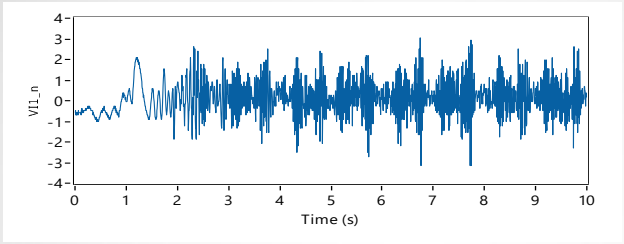
Walking Aids Net Nodes

2wheelsW prototype

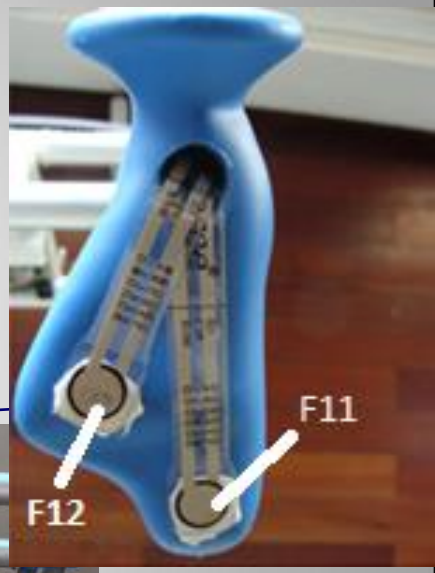


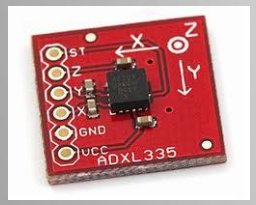


Force sensor

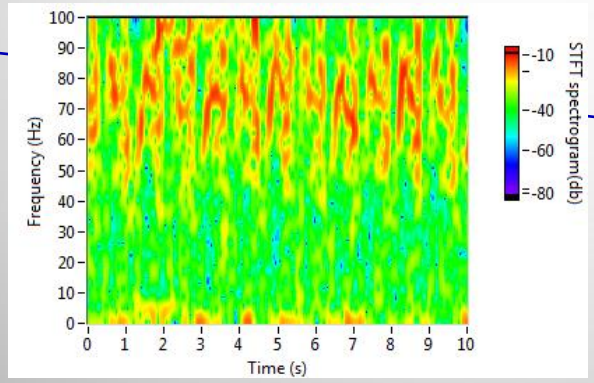


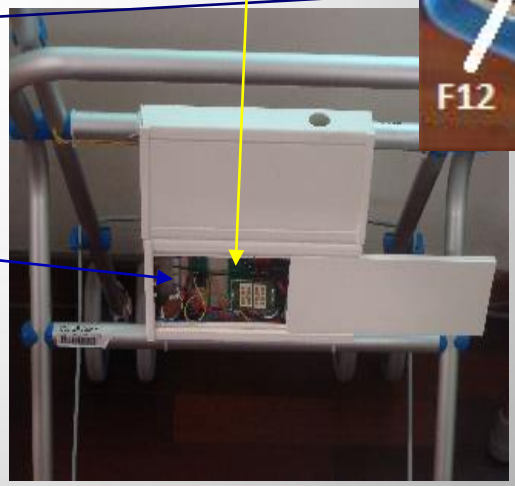
Single Doppler Radar





3D accelerometer





O. Postolache et Al.
ICST 2011, NZ

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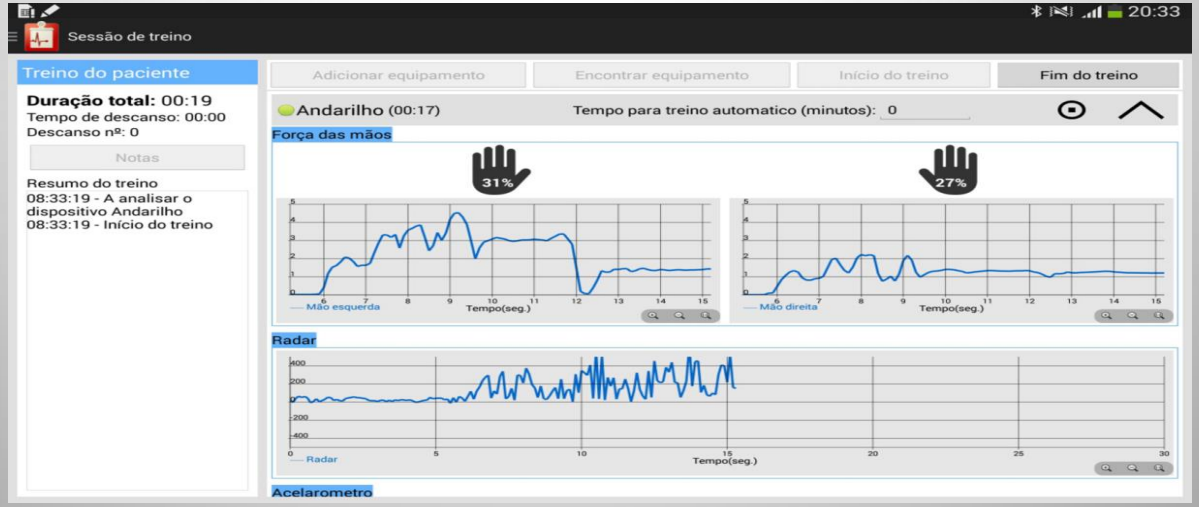
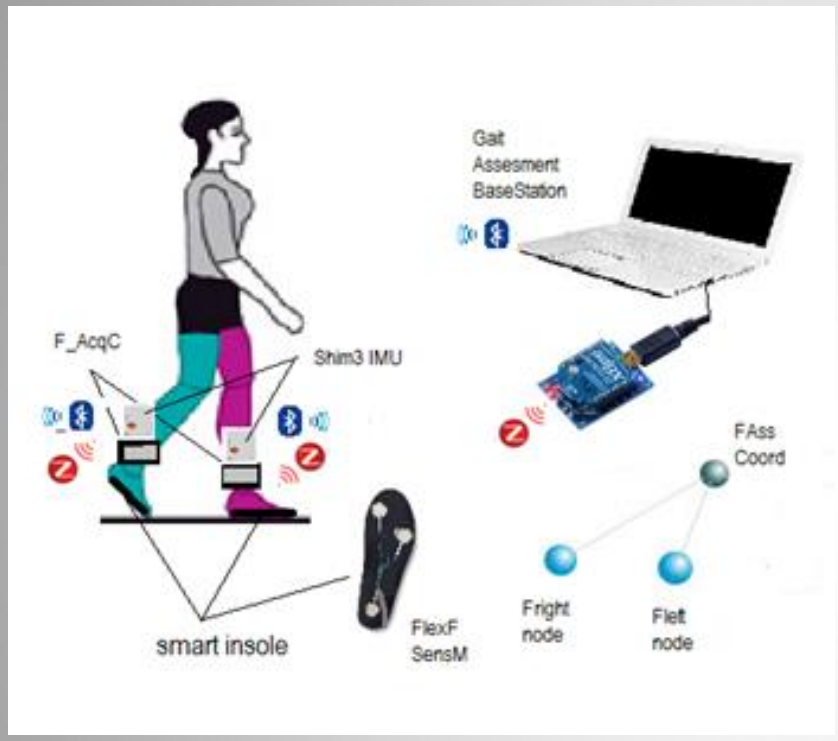
Walking Aids Net Nodes

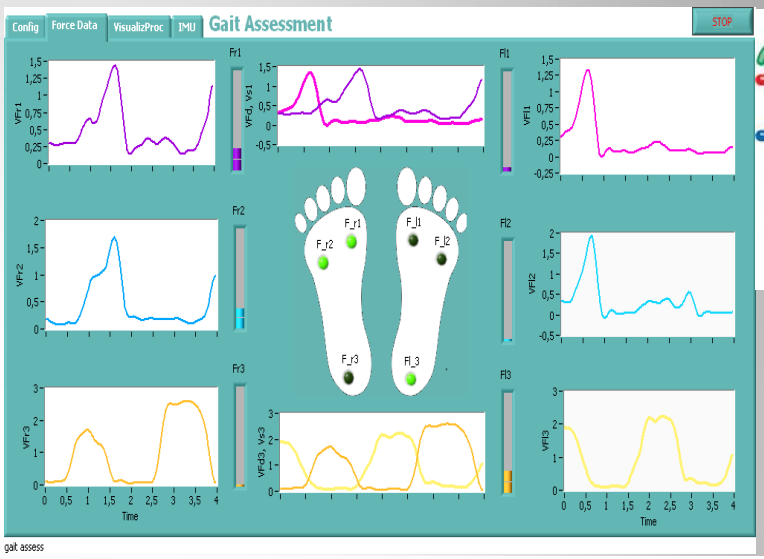
2wheelsW mobile software

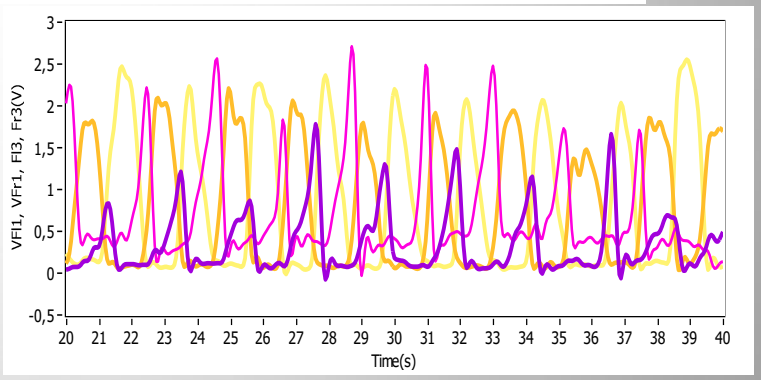


Wearable Gait Rehabilitation

Smart Insole based PRS







voltage signals normal gait from metatarsal calcaneus area

ATEE 2015, Bucharest, Romania

IEEE IMS Seminar, TCS Innovation
Kolkata, August 31

Wearable Gait Rehabilitation

Smart Insole based on FBG array

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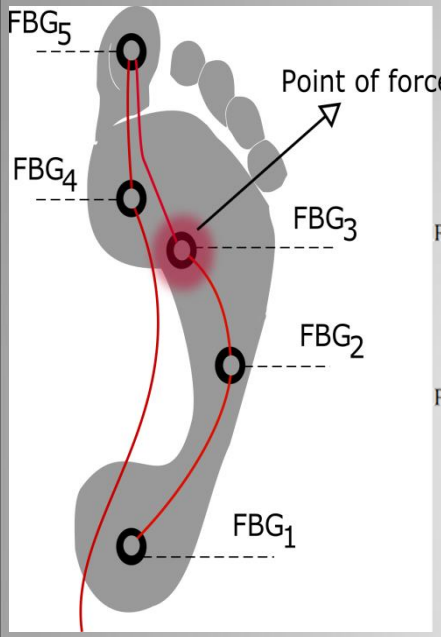
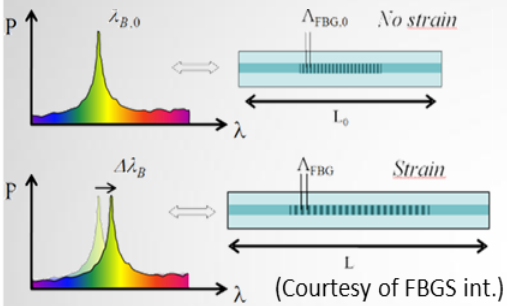
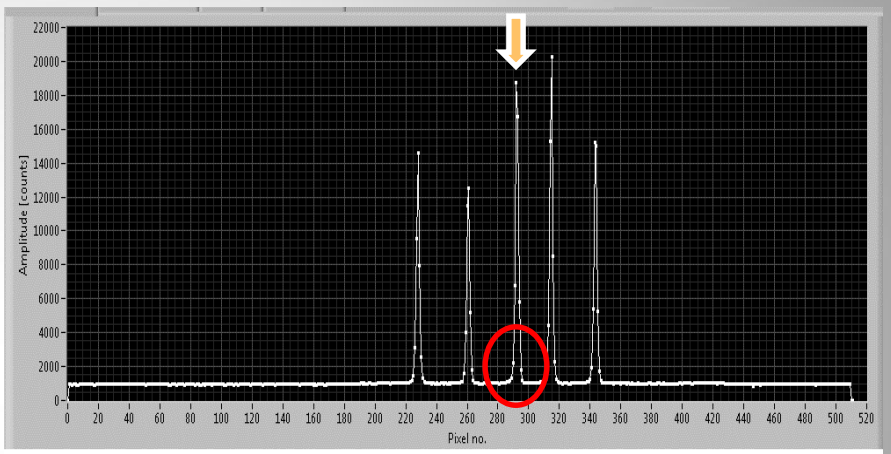
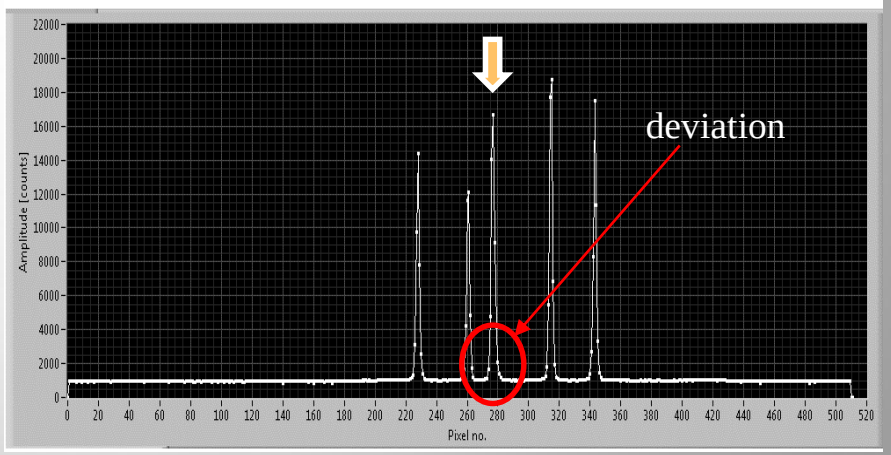
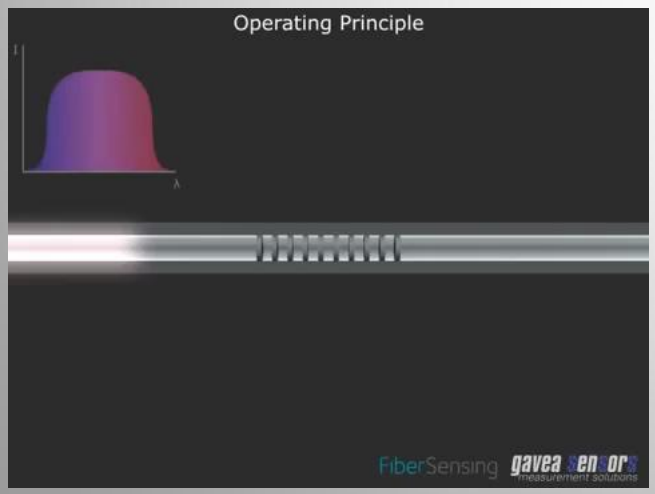




(Courtesy of FBGS int.)



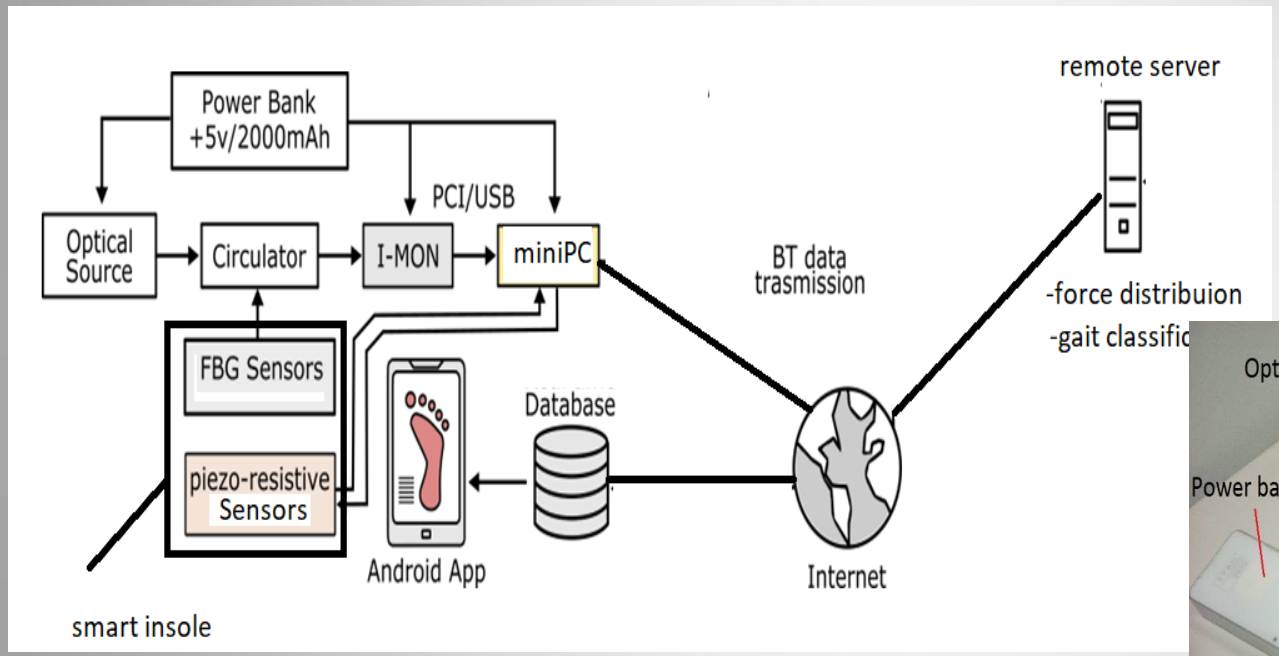


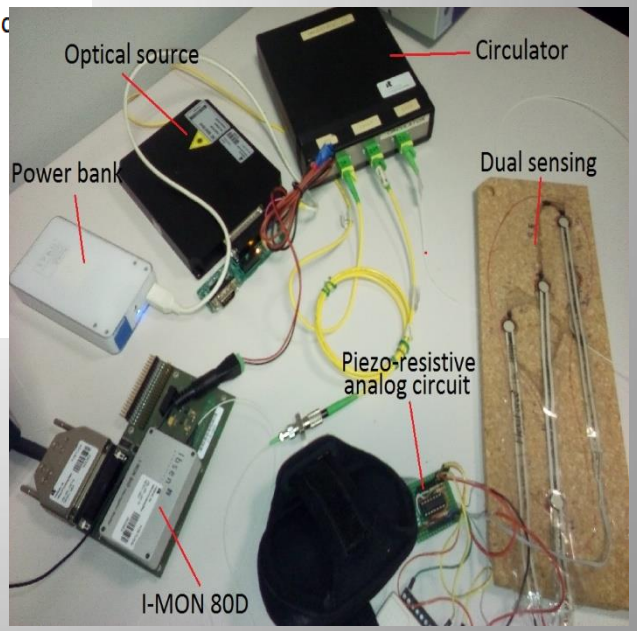


Wearable Gait Rehabilitation

Smart Insole based on FBG array

- The Fiber Bragg Gratings Architecture





- Insole Fiber Bragg Grating (FGB) Network prototype
  - Were used 5 t o 6 FBGs
  - Force measurement using PRS Tekscan A201

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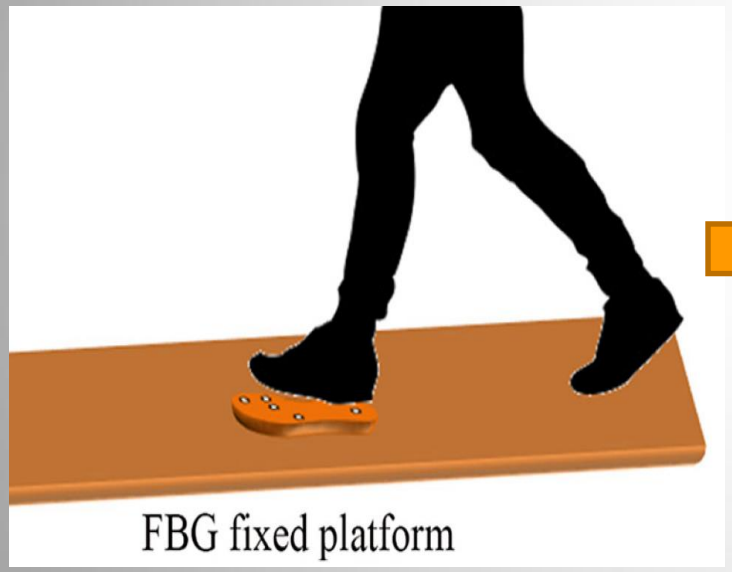
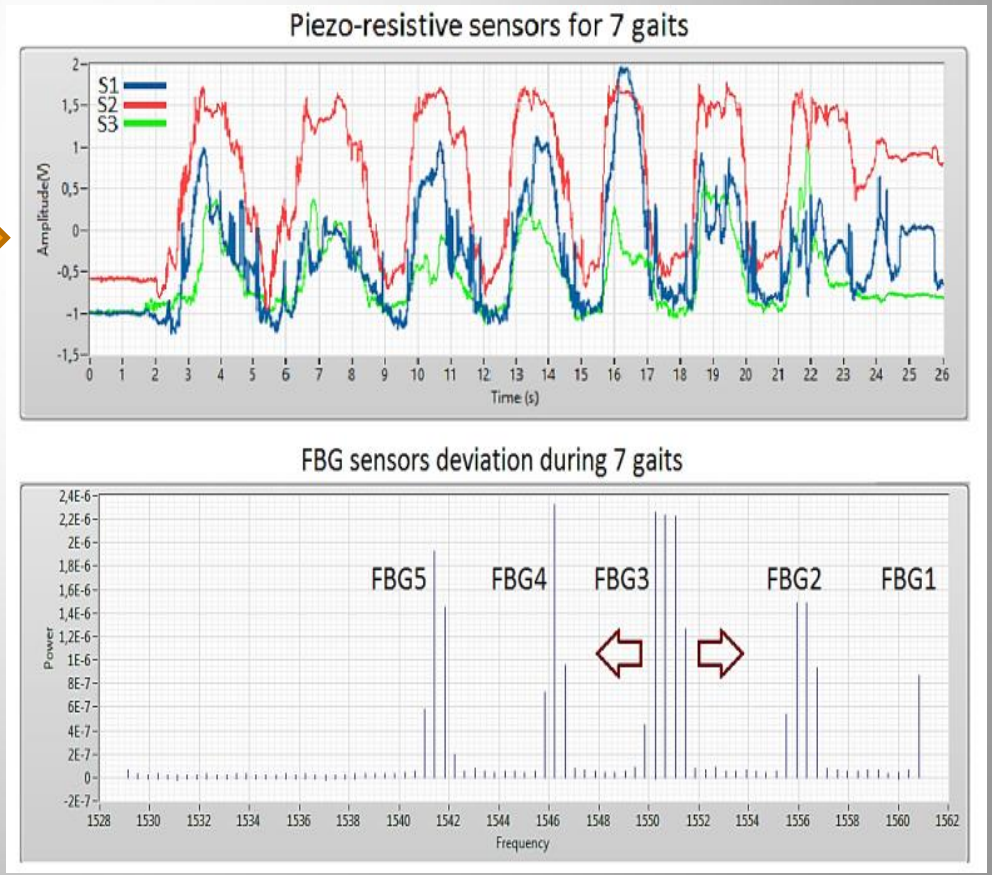
Wearable Gait Rehabilitation

Smart Insole based on FBG array

Smart Insole Comparative Results

piezo-resistive sensors with FBGs sensor network





DOMINGUES, M.F, Postolache, Journal of Biomedical Optics, v. 22(9), pp. 1-8, 2017.

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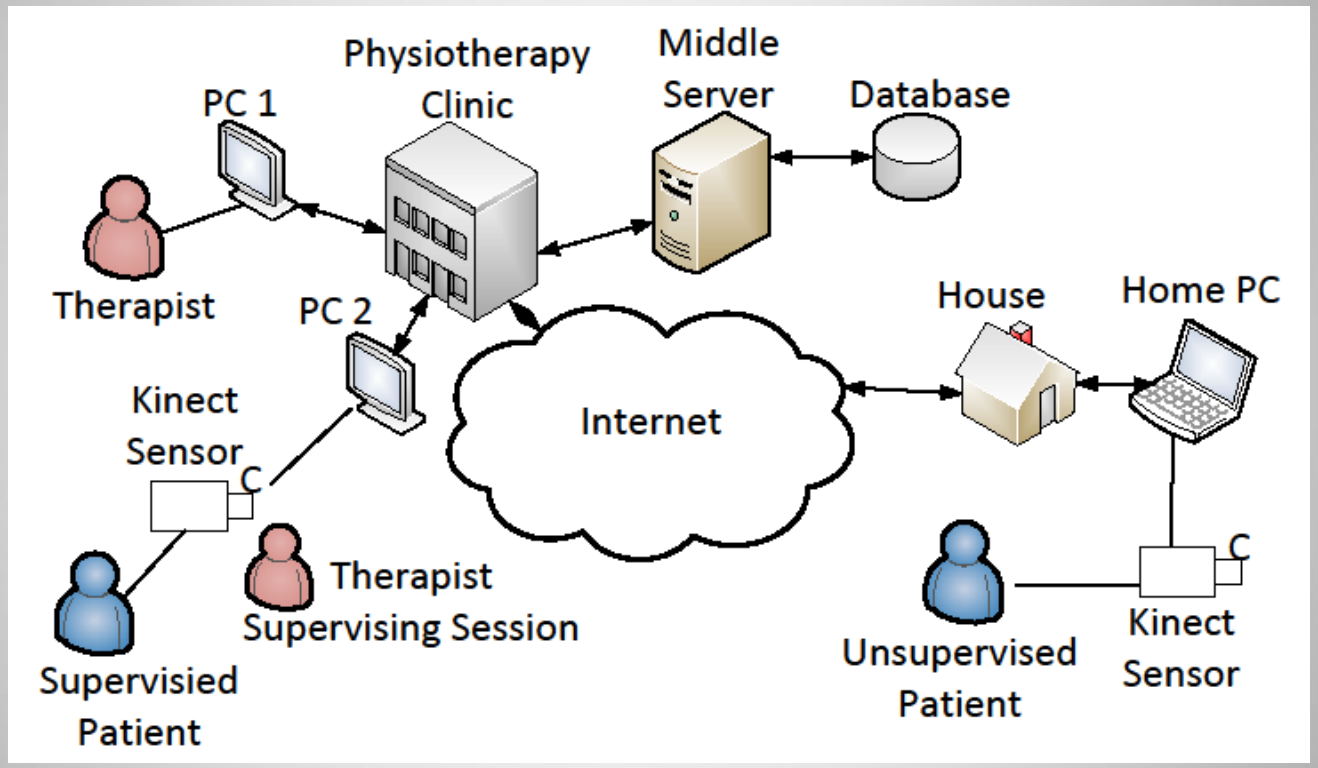
Remote sensing and IoT for smart physiotherapy

Kinect Computation Architecture



Kinect Serious Games on the client side are *GRANTED*

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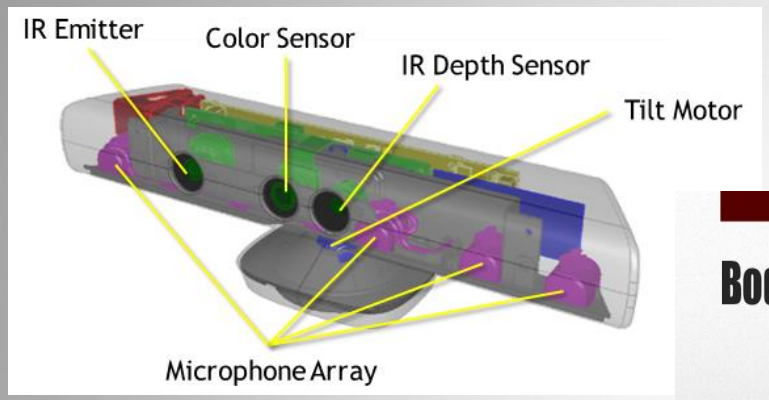
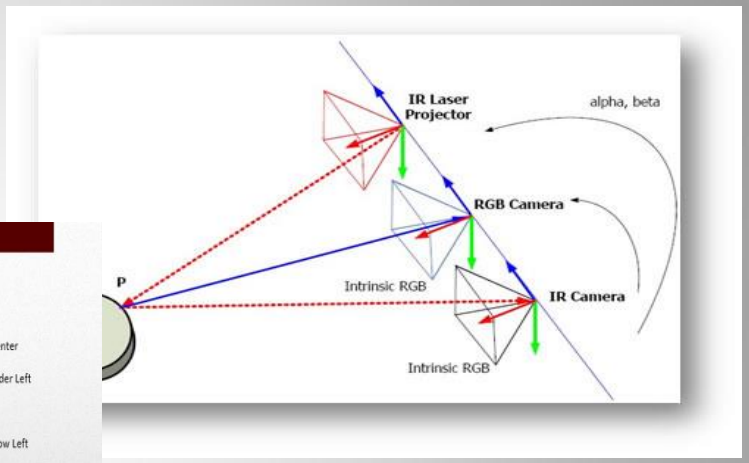
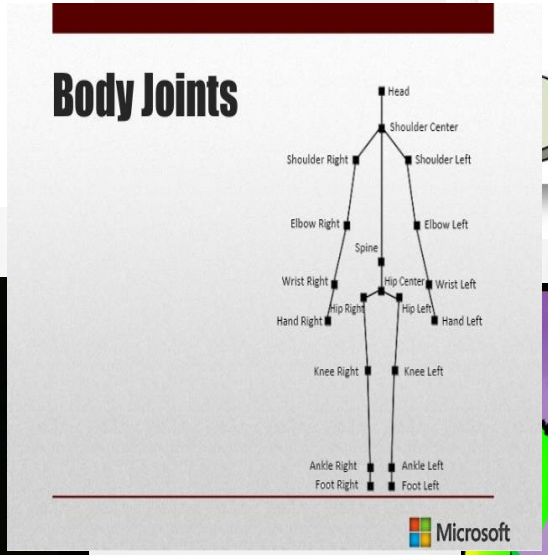
Unobtrusive sensing of physical rehabilitation

Kinect sensor







IR speckle pattern

20 body joints SDK

Depth estimation

NUI based Remote Sensing for physical rehabilitation

Kinect Serious Games

- Serious Games concept refers to the use of computer games without the main purpose of providing pure entertainment,

- Therasoup,

- Serious games based therapy (TheraGames) is currently gaining a lot of interest by the healthcare community.
- AppleHarvesting

- JustPhysioKidding

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Kinect Serious Games For Rehabilitation

Therasoup v2.0

Unity 3D and C# technologies were used to develop the game

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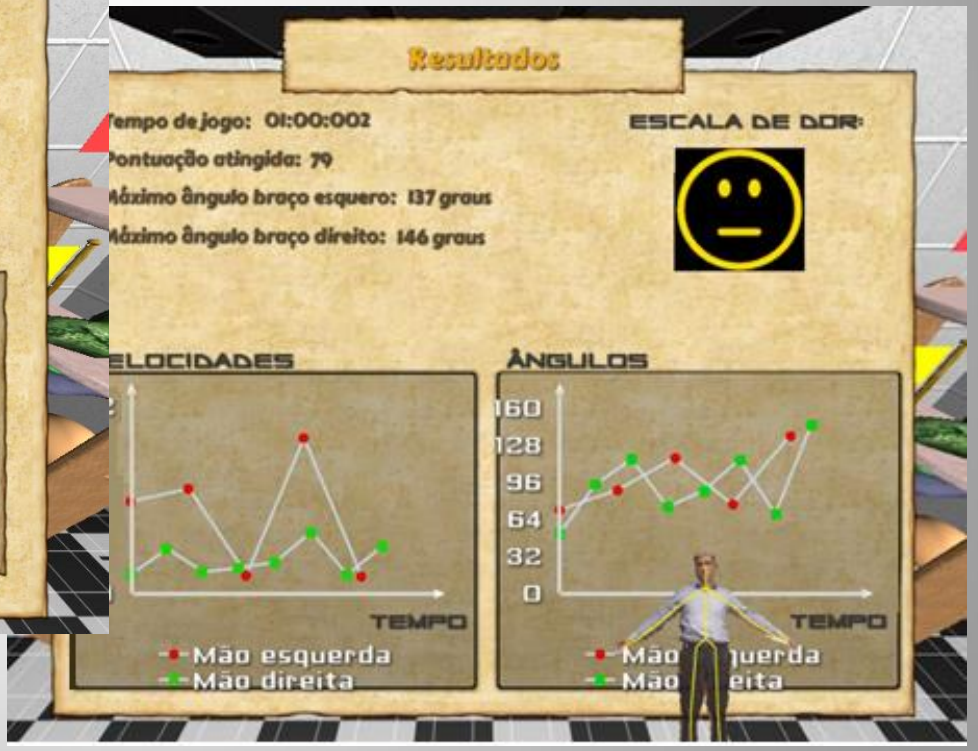
"Therasoup" Kinect Serious Games

training metrics and pain scale

Pain scale game GUI

Training outputs



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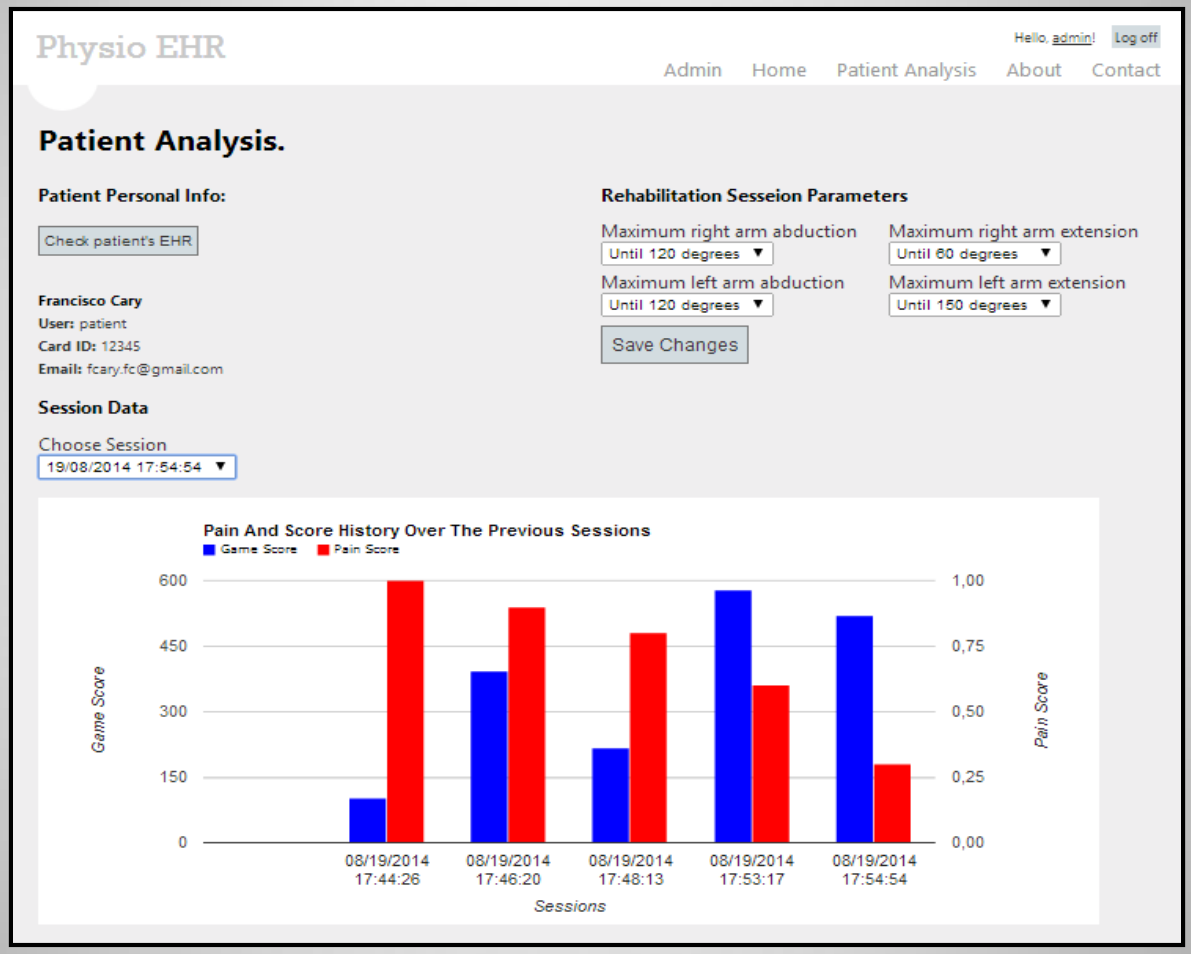
Kinect Serious Games For Rehabilitation

Therasoup v2.0



Microsoft® .NET™

web based: game configurator

game score and pain assessment

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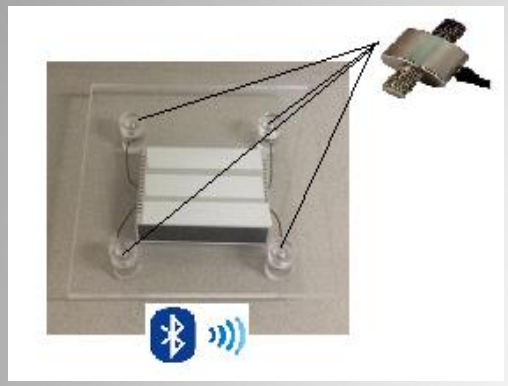
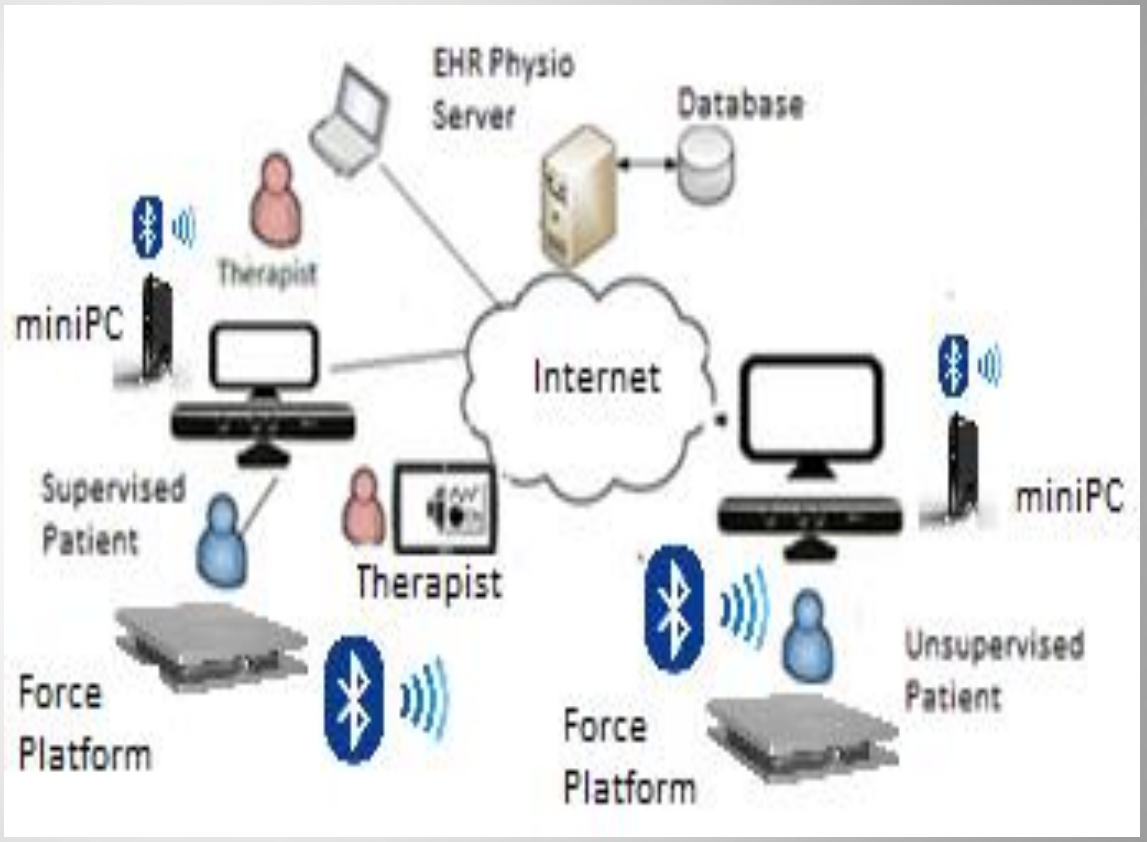
Smart Physiotherapy Tailored Environments

Kinect & Force Platform





IoT through Internet connectivity of the *Kinect Client* (miniPC)

O. Postolache et. al:MeMeA 2016

Gaming Tests

COP amplitudes

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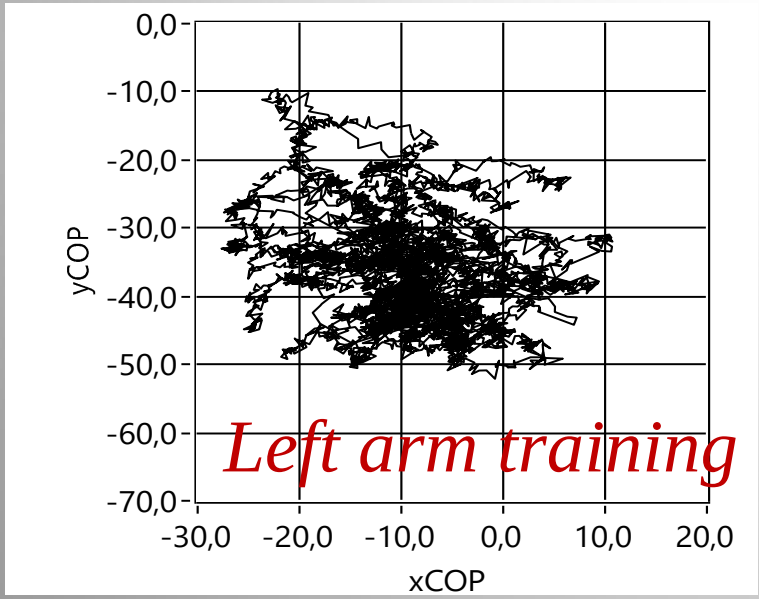
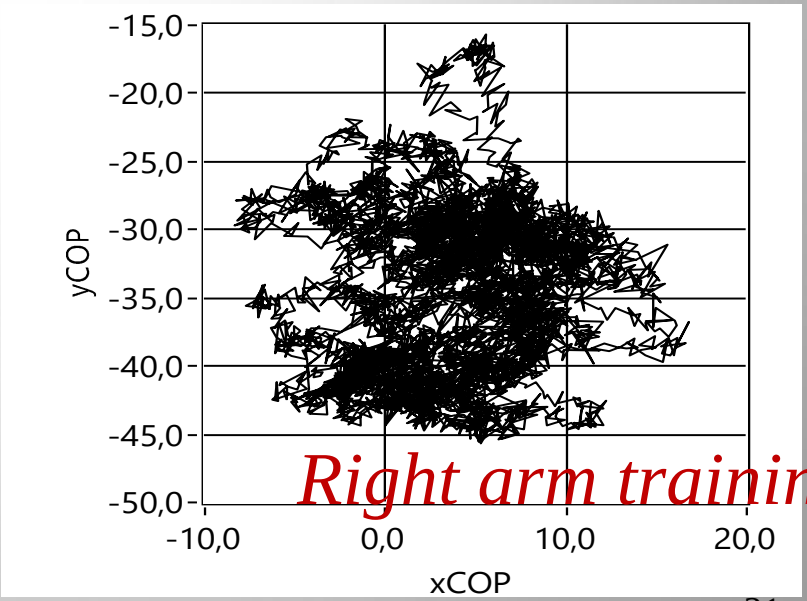
subject	metrics	L game (mm)	R-game (mm)	L-R game (mm)
I	A-P amp	25.15	31.49	28.82
	M-L amp	33.1	24.87	19.11
II	A-P amp	30.39	17.57	39.27
	M-L amp	26.33	18.22	35.54

Amplitudes

A-P antero posterior

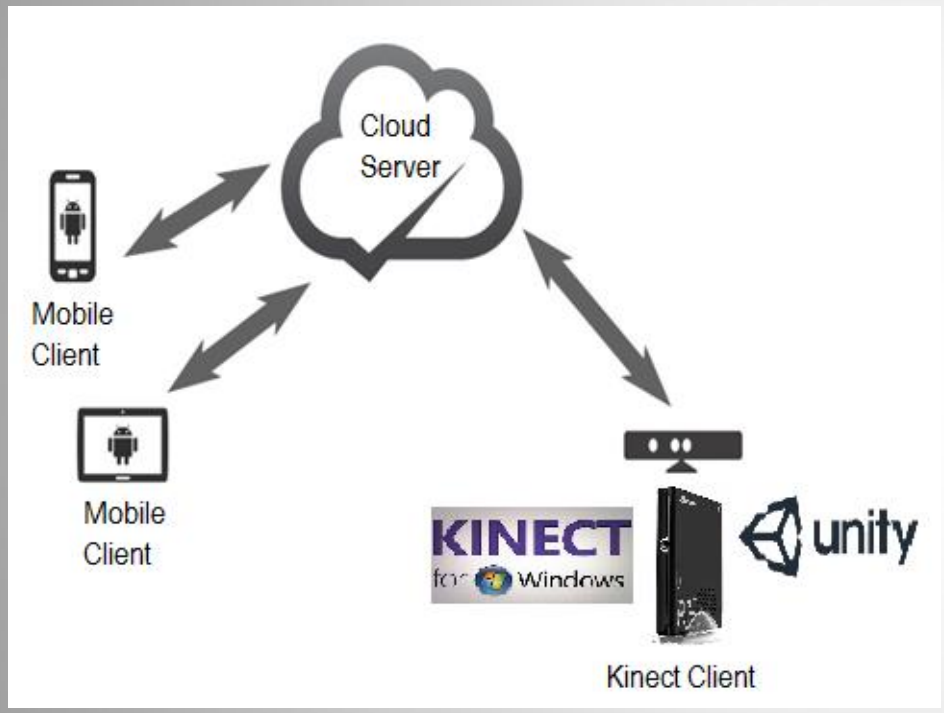
M-L medio-lateral





Kinect Serious Game for Rehabilitation

"Apple Harvesting" Game



Computation architecture
Based on API

Implemented VR game scenario

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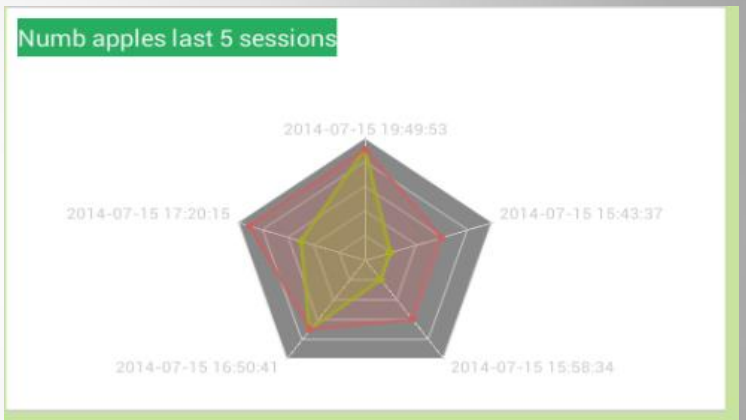
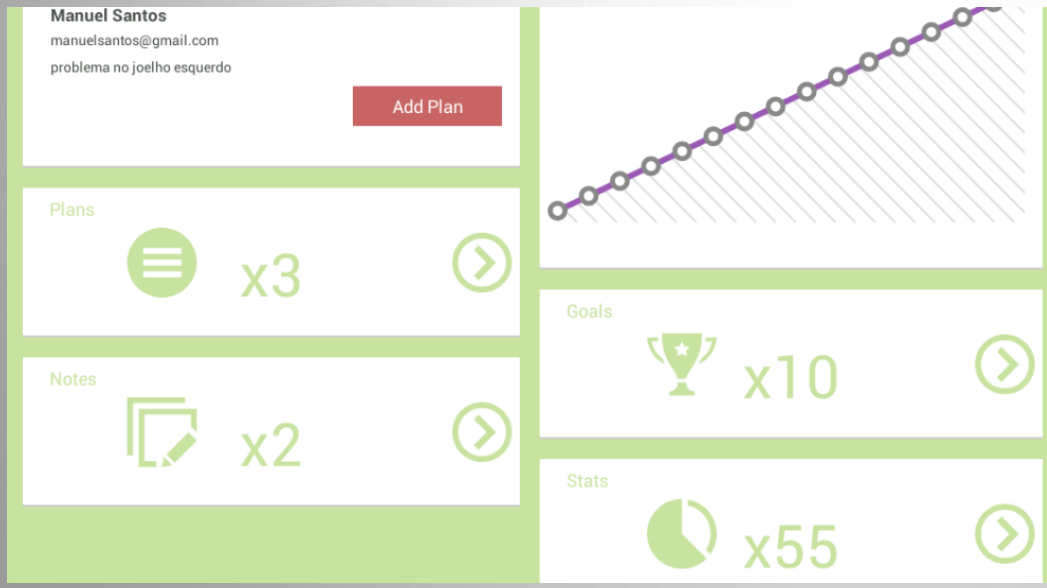
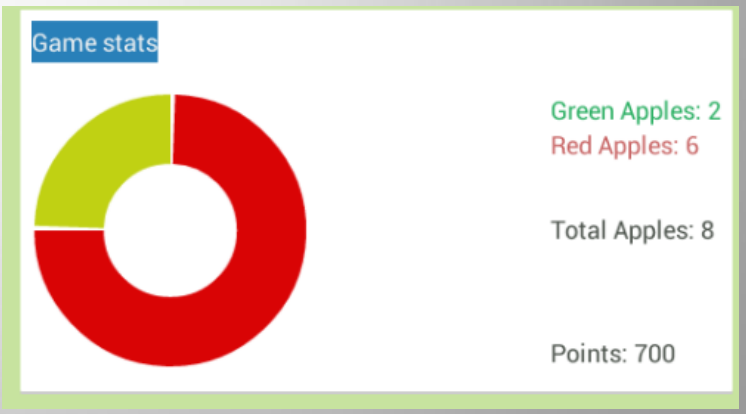
Kinect Serious Games For Rehabilitation

Objective Evaluation results on APP interface







Kinect Serious Game for Rehabilitation

Tailoring "Apple Harvesting"

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Kinect Serious Game for Rehabilitation

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Tailoring "Apple Harvesting"

Stroke – hand rehab phase I

Kinect Serious Game for Rehabilitation

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Tailoring "Apple Harvesting"

Stroke Phase rehab phase II

Kinect Serious Games For Rehabilitation

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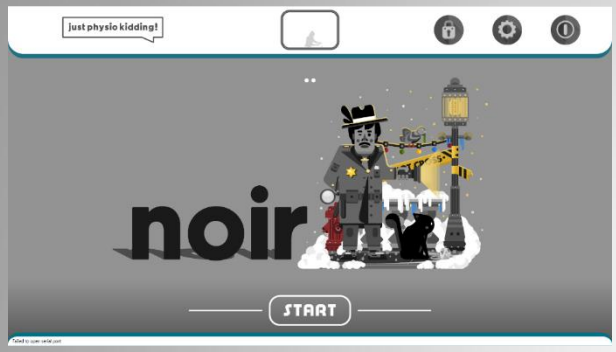
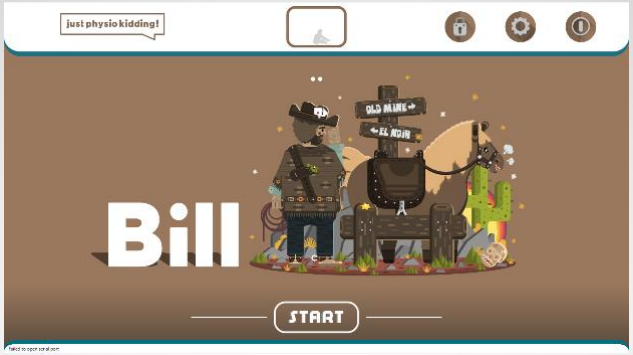
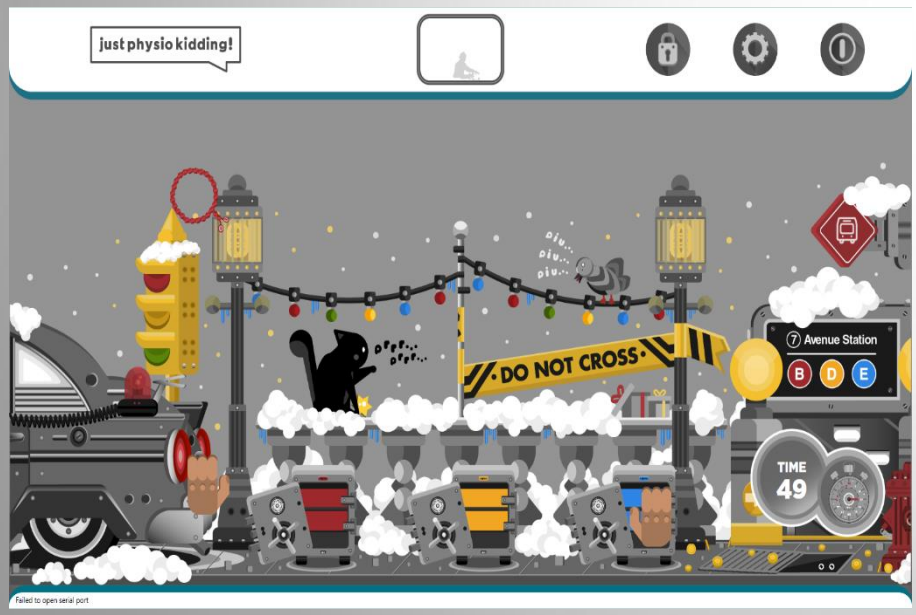
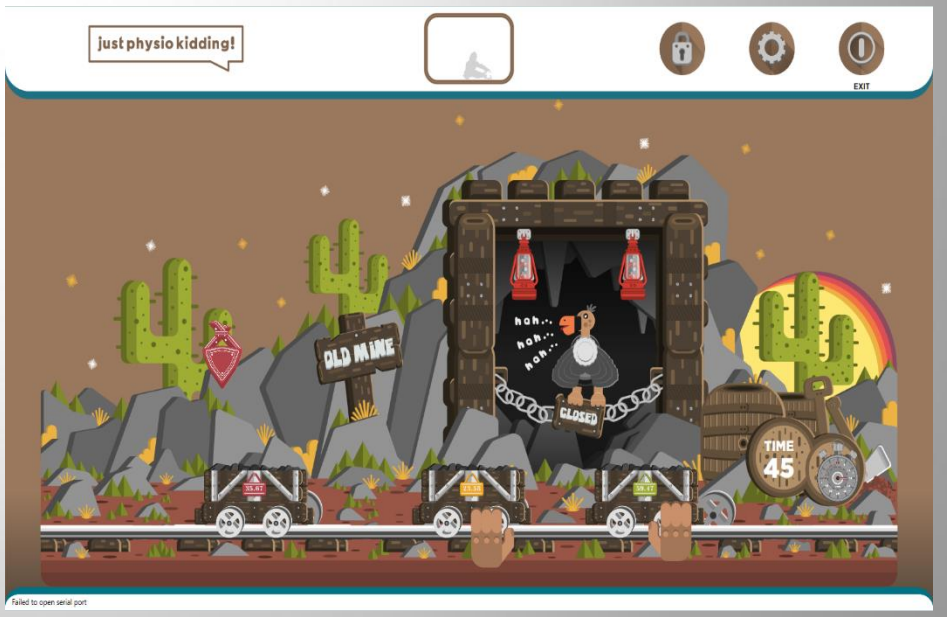
Cerebral Palsy

JustPhysioKidding Gaming Scenarios









Kinect Serious Games For Rehabilitation

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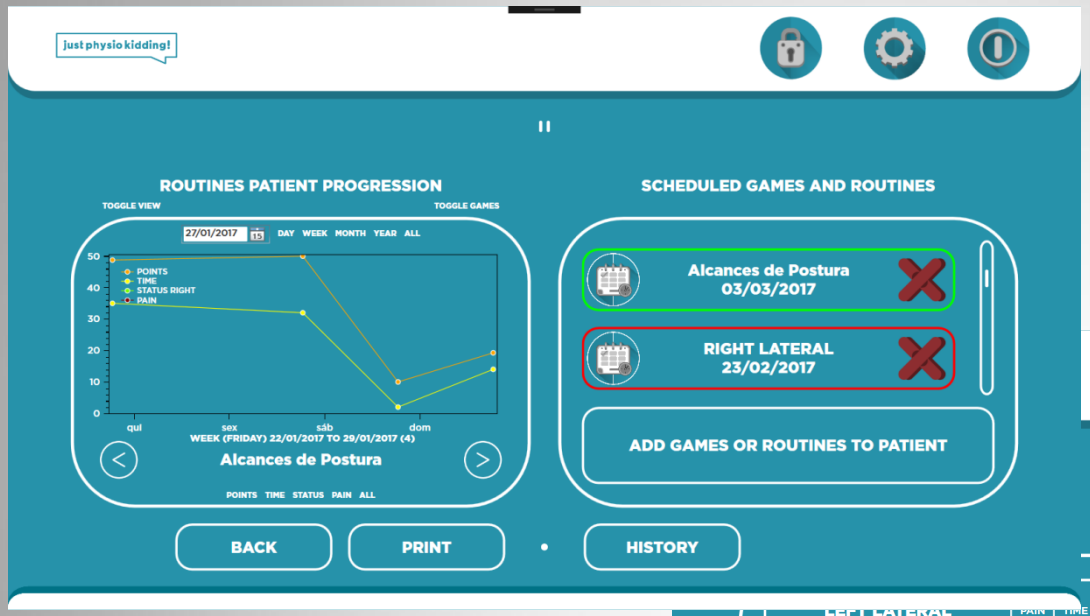
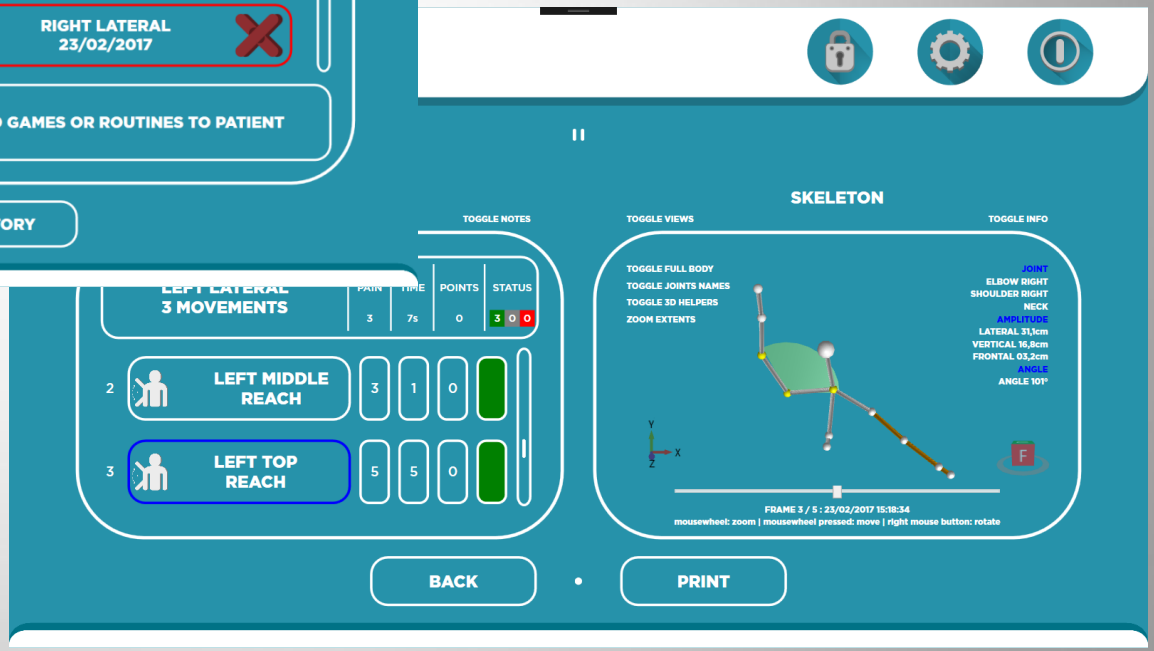
JustPhysioKidding





Results GUI
Plan and Motion Reconstruction

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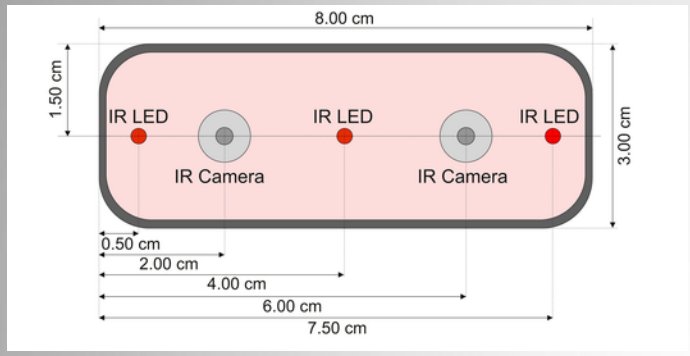
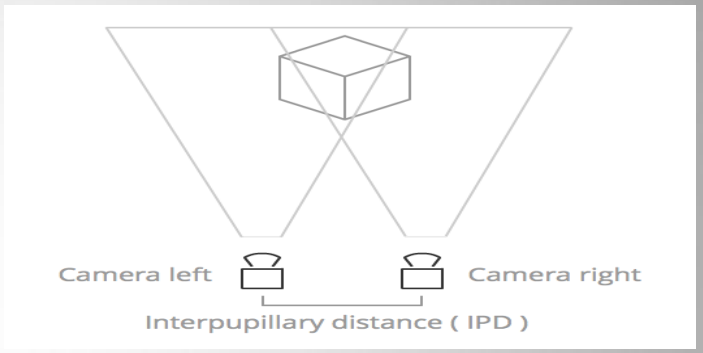
Serious Game for Physical Rehabilitation

Leap Motion Controller





- two cameras track infrared light produced by three infrared LEDs.

3D stereoscopic image provides→Gesture and position tracking with sub-millimeter accuracy

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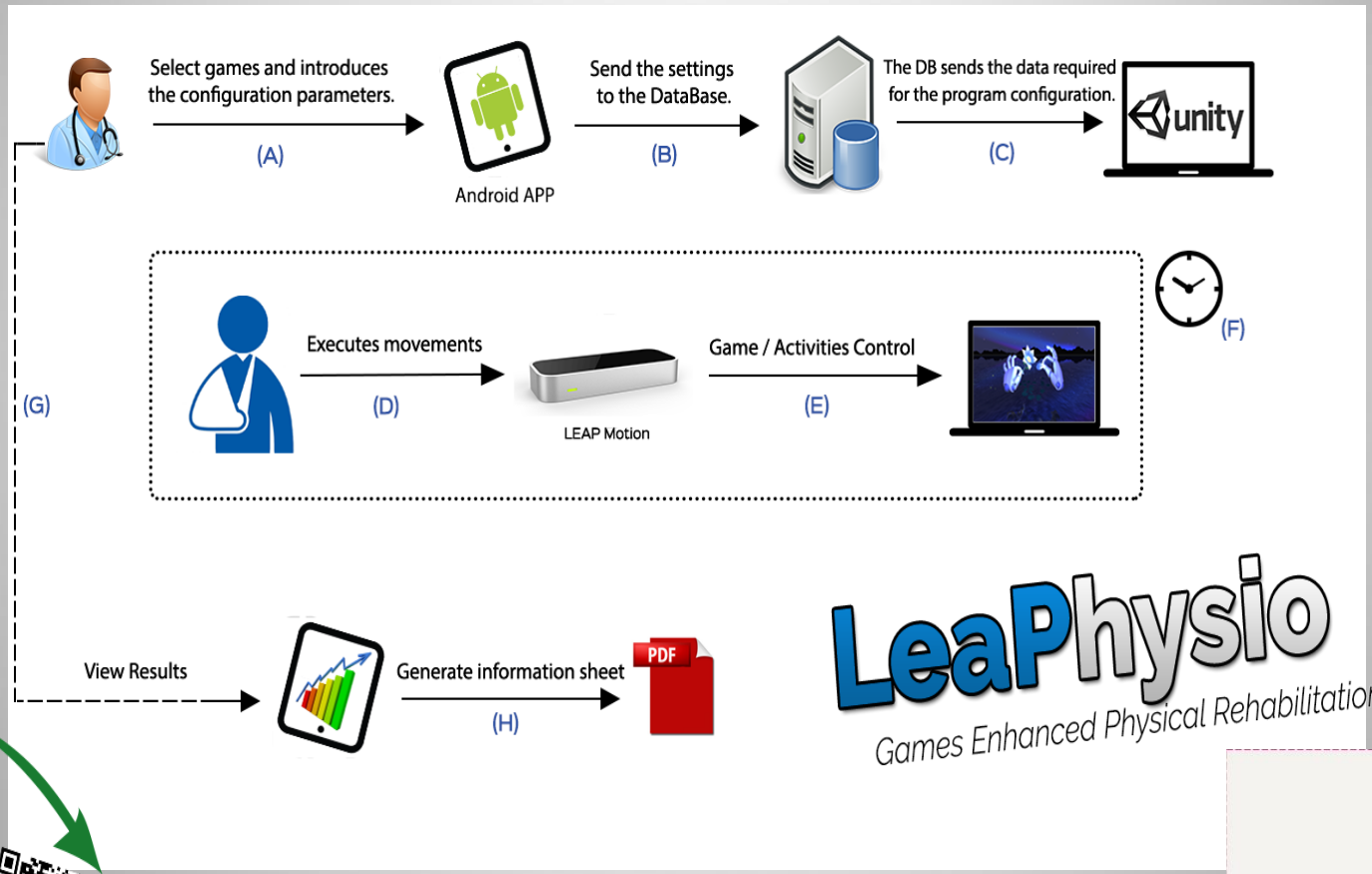
Serious Game for Physical Rehabilitation

Leap Motion -Serious Game Platform



LeaPhysio
Games Enhanced Physical Rehabilitation

Name: LeaPhysio ID: 123456789 Scan Me

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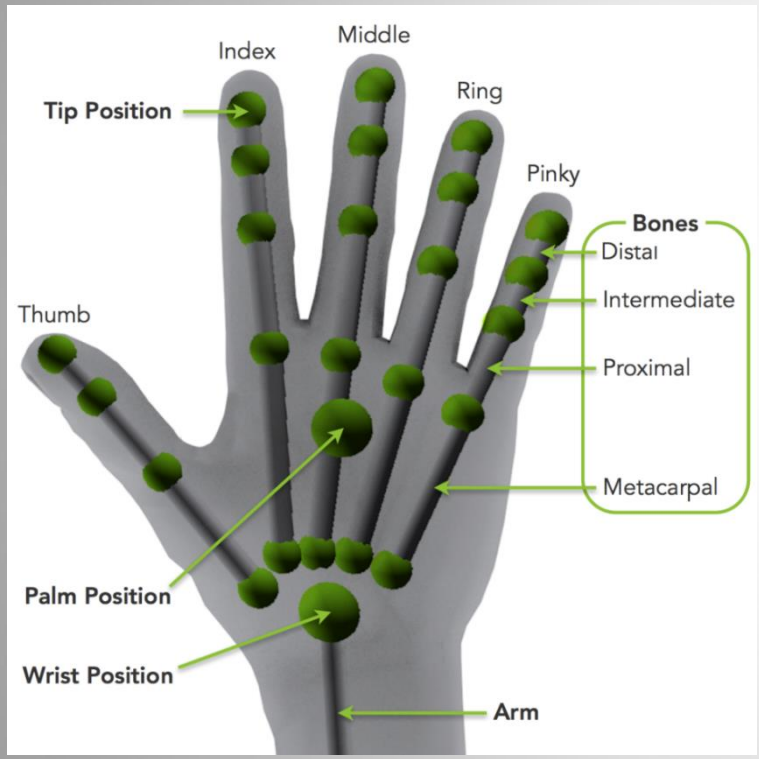
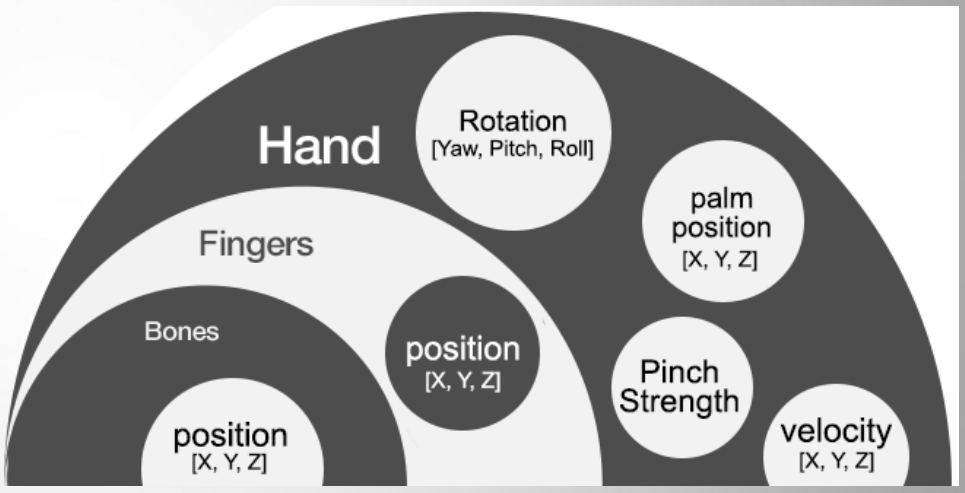
Serious Game for Physical Rehabilitation

Leap Motion -Serious Game Platform





- Extended Adaptation of the Game to the Cognitive Rehabilitation Needs are considered

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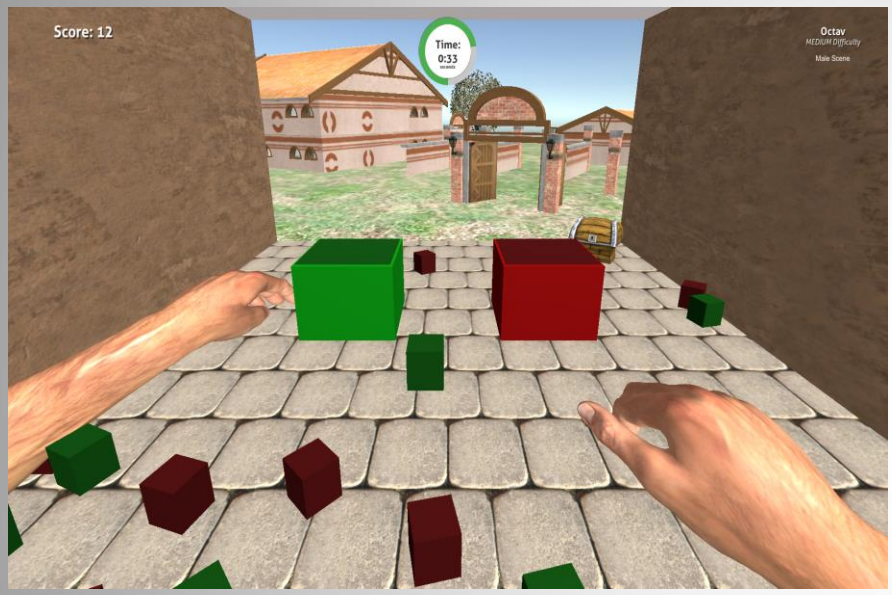
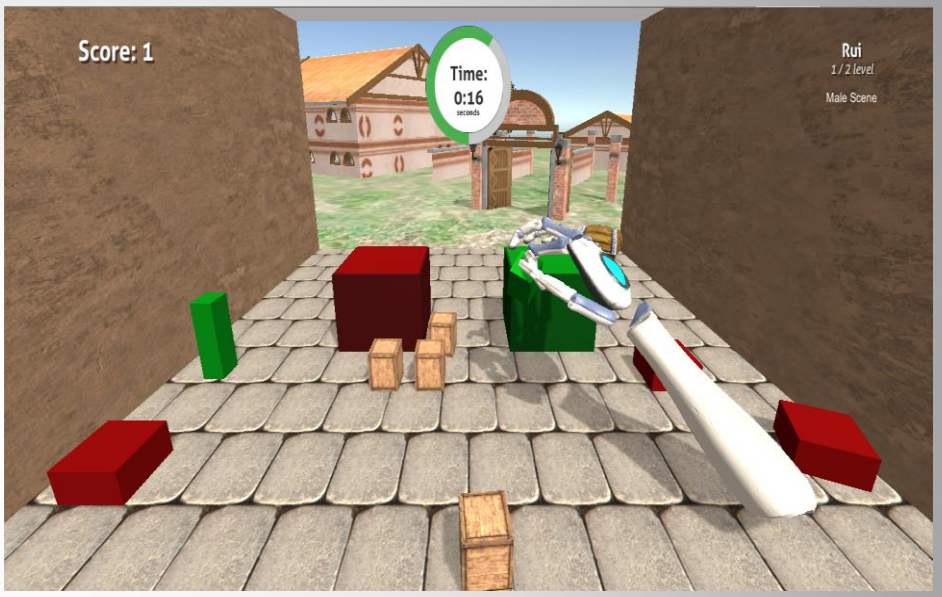
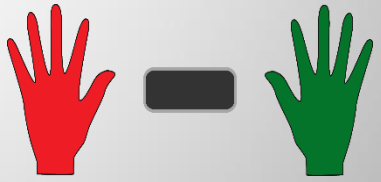
Games Enhanced Physical Rehabilitation

➢ Game: **Collect Cube**







- The user hands are selected according with: male, female, children (robo) → to increase the player motivation .
- The physiotherapist can chose the training plan for particular hand

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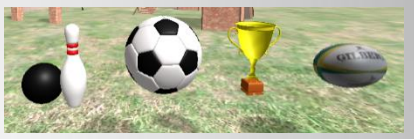
Games Enhanced Physical Rehabilitation

➢ Game: **Collect Cube**

- **THEME**: OBJECTS

- **CUBES**



Sports

Animals

Fruits

- **BOXES**

- Extended Adaptation of the Game to the Cognitive Rehabilitation Needs are considered

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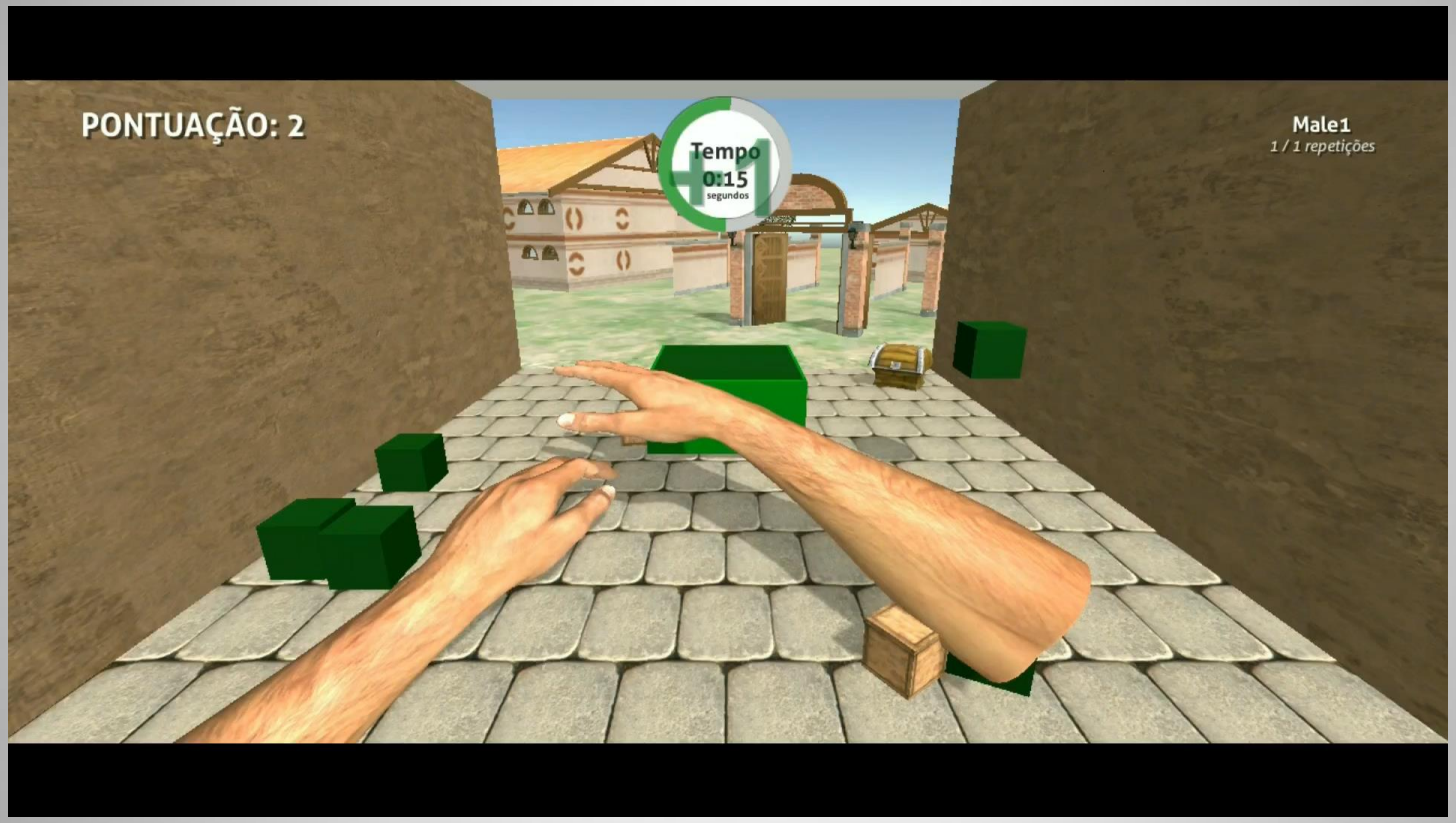
Game: **Collect Cube**



- Motor and cognitive rehabilitation together

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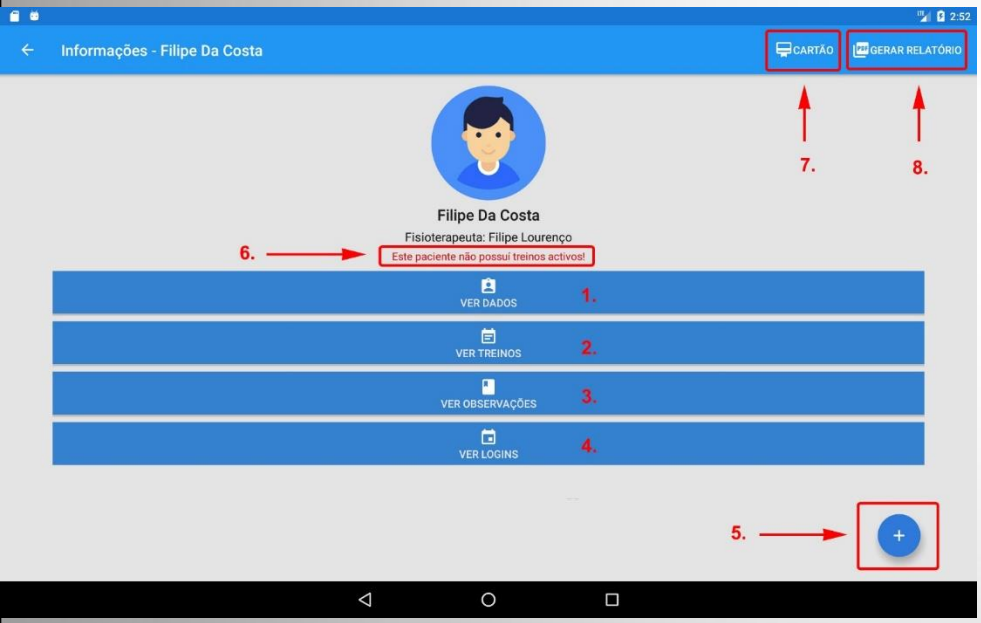

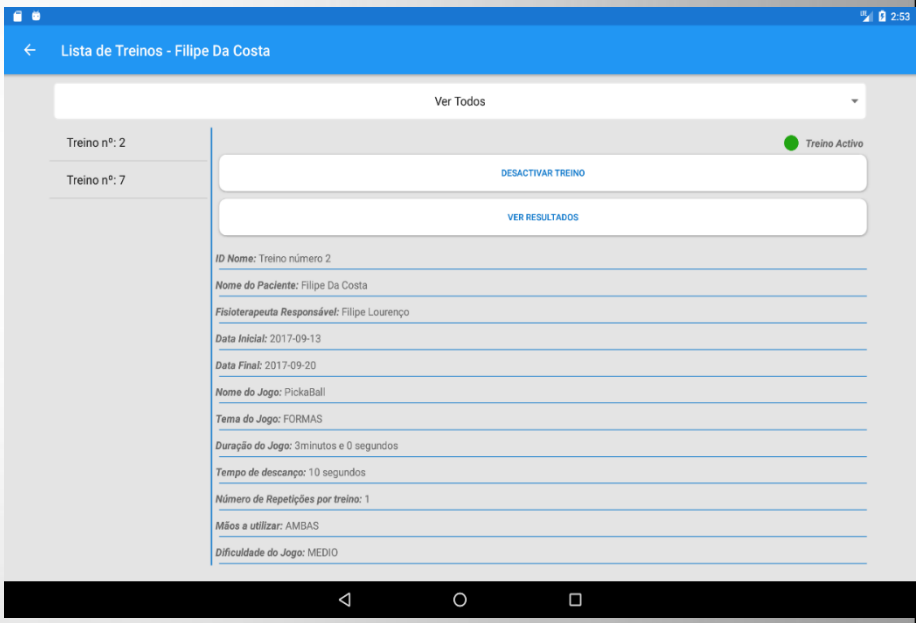

user and training plan records

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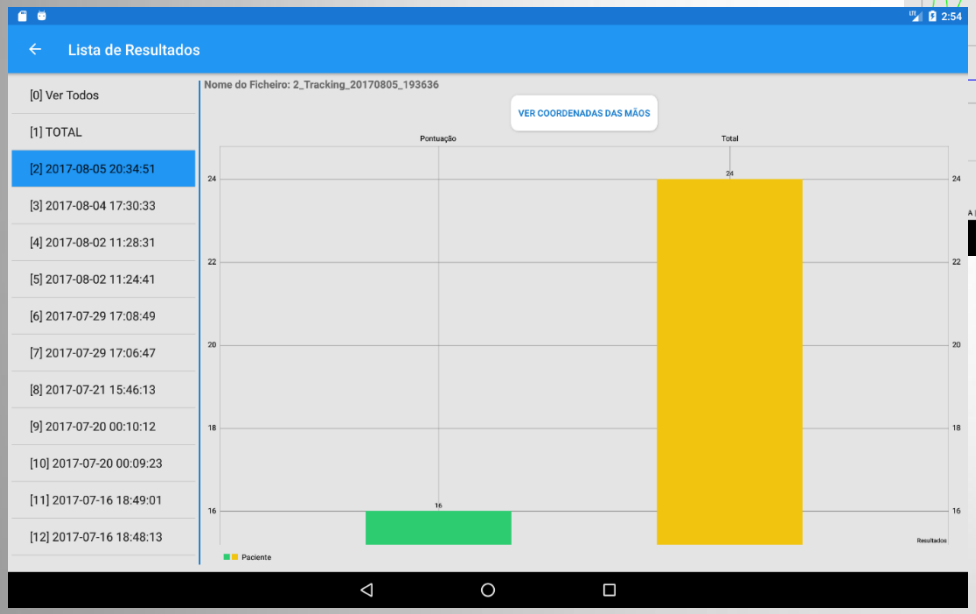
Score and joint position *by date*



Infrared Thermography for Physical Therapy

Objective evaluation of muscular activity

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Infrared Thermography: Every object whose surface temperature is above absolute zero (-273 °C) radiates energy at a wavelength (short wave 3-5um and long wave 7-9um) corresponding to its surface temperature.

To obtain Thermographic Image highly sensitive (0.05ºC) infrared camera (e.g. FLIR E60) capture thermal radiated energy with good accuracy (error 2% of reading).

FLIR Tools+ and Thermonitor™ software applied → to extract specific temperatures (min, max, avg).

Infrared Thermography for Physical Therapy

Unobtrusive sensing of muscular activity

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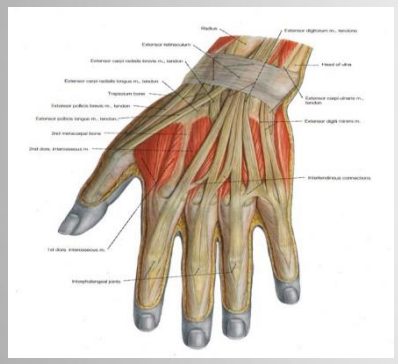
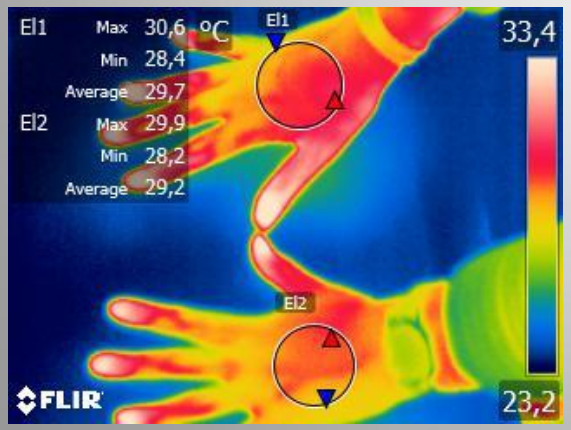




Thermographic images provides patient cutaneous temperature in non-intrusive mode →the intensity of muscular activity is revealed.

Temperature increase caused by increased blood flow during the physical therapy sessions.

Flir Tools+ is used to extract the temperature values in different cutaneous regions

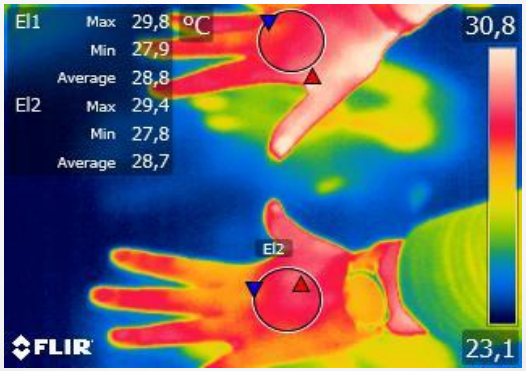
VR versus Real Scenario Serious game

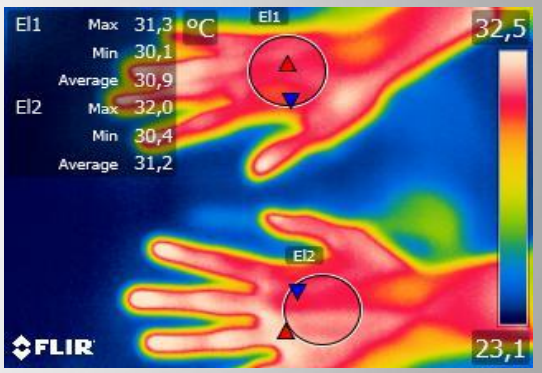
Training Effectiveness Tests & Results

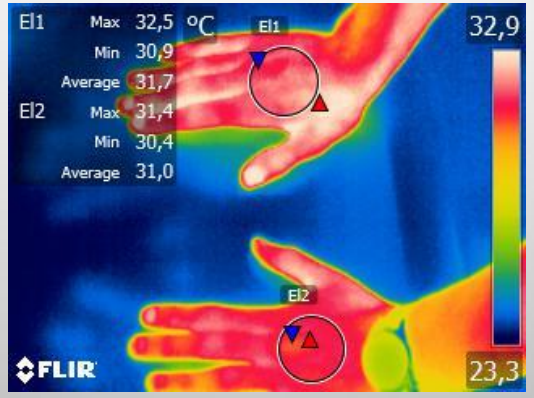
How about real training versus virtual training using “Cubes”?

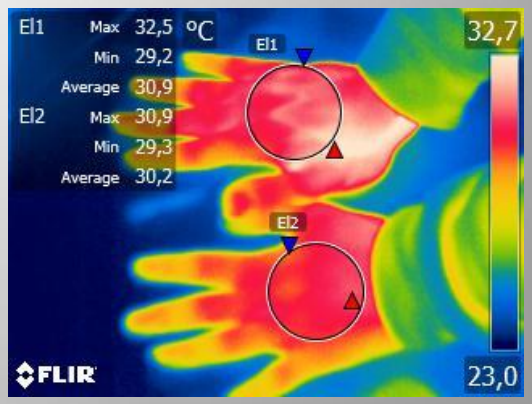
4 volunteers, 4 tests (0.5min, 1 min, 1.5 min, 2min

→ *Thermographic images*









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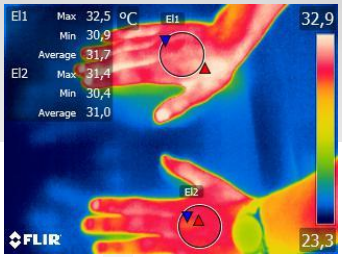
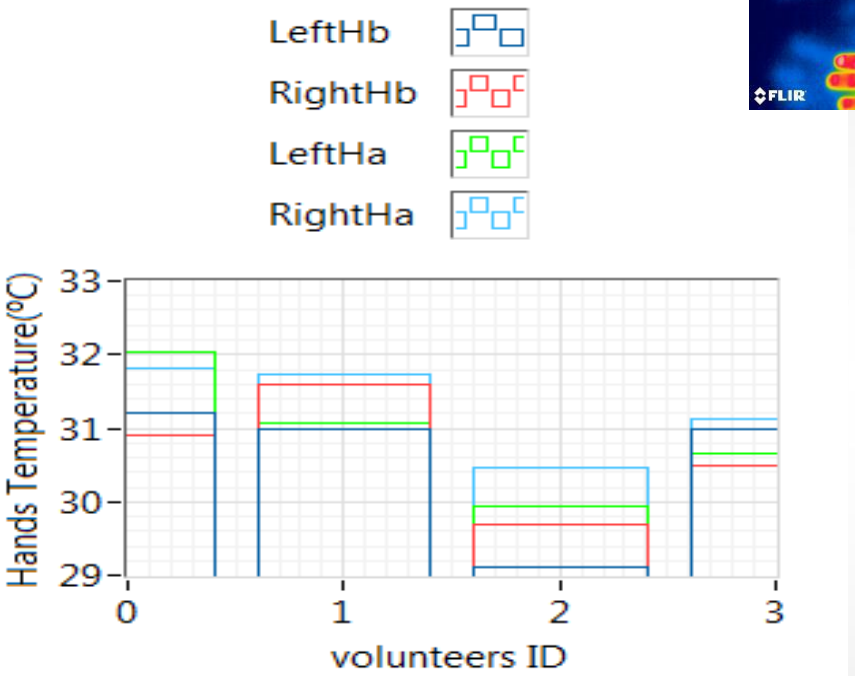
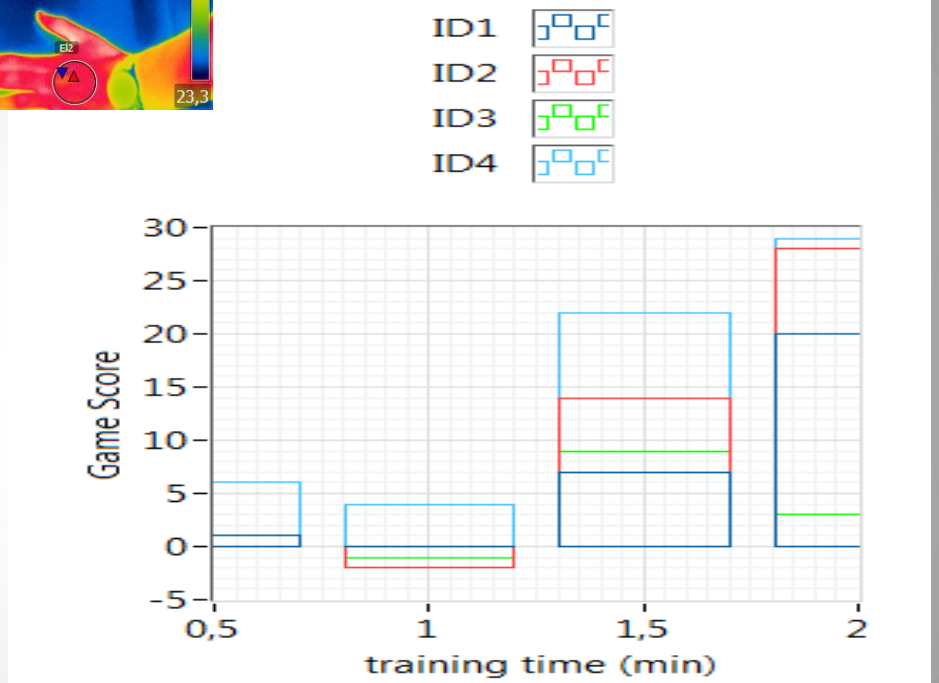
Infrared Thermography for Physical Therapy

Unobtrusive sensing of muscular activity







Average temperature evolution of hand skin temperature before and after 2 min training

Score Evolution for different training durations (IDi volunteer ID)

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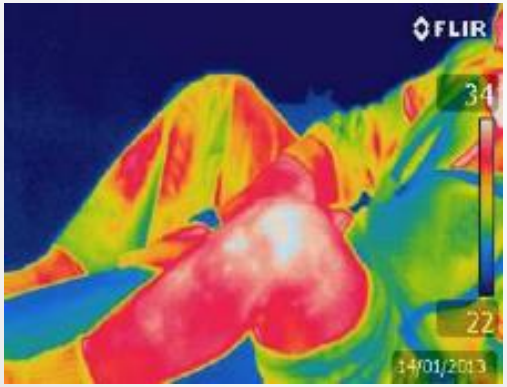
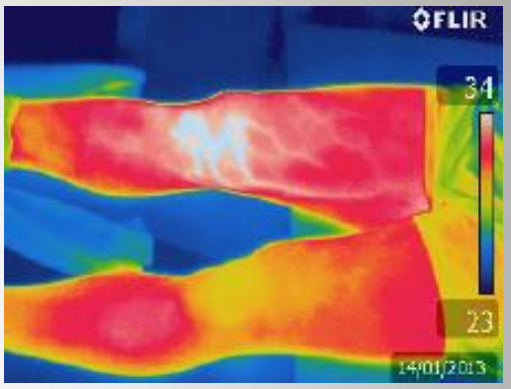
Objective evaluation of Physical Rehabilitation

Thermography for Knee Recovery Assessment





Thermal images provided by the FLIR E60 clearly indicate inflammation of the knee and can be used to visualize the knee recovery in time.

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Conclusions

- Smart Physiotherapy expressed by tailored environments expressed by virtual reality and smart objects and wearable devices assures an increased quality of services →reduced rehabilitation time
- Personalized serious games with natural user interfaces data storage and analysis associated with smart physiotherapy IoT compatible → increase the patient motivation and physical therapy effectiveness.
- Remote sensing technologies expressed by Kinect and Leap Motion Sensors and Thermography play an important role in objective evaluation → physical therapy outcomes.

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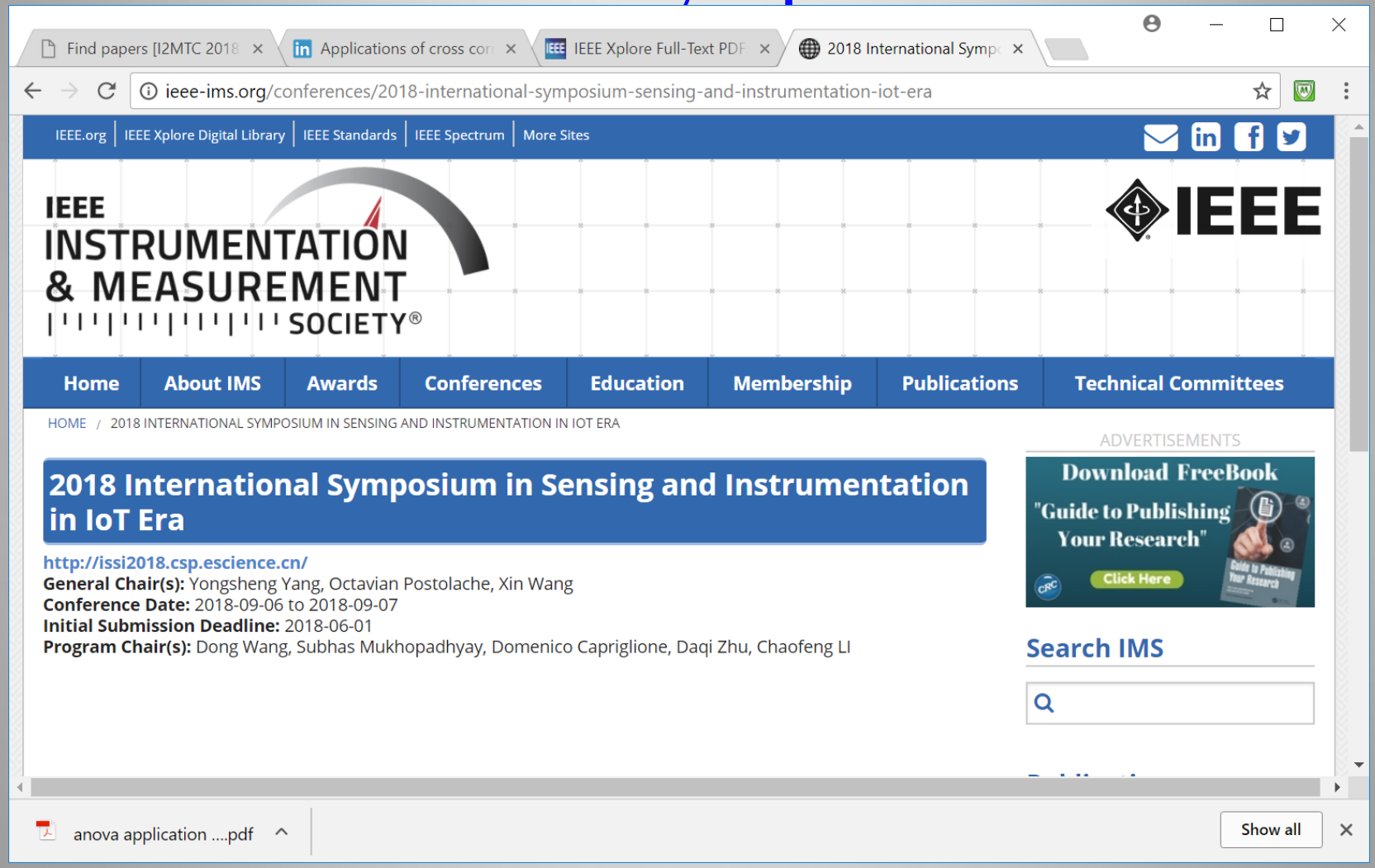
IoT Symposium



Acknowledgements

- The work was supported by Instituto de Telecomunicacoes, Project WeHope and Fundação para Ciencia e Tecnologia, Project TailorPhy.

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Thank you!