

**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

IEEE SM Octavian Postolache

IEEE IMS Distinguished Lecturer

IEEE IMS TC-13 Chair, IEEE I&M Portugal Chapter Chair

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– [Kristen Donnell](#)

AdCom (2016-2019);

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- 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.

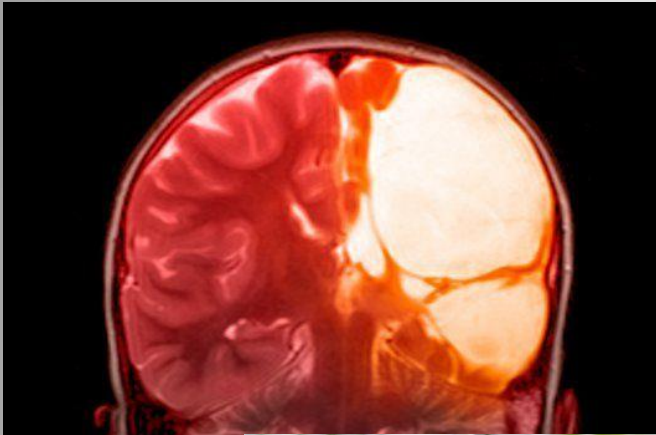
15 million people suffer stroke worldwide each year (WHO).

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

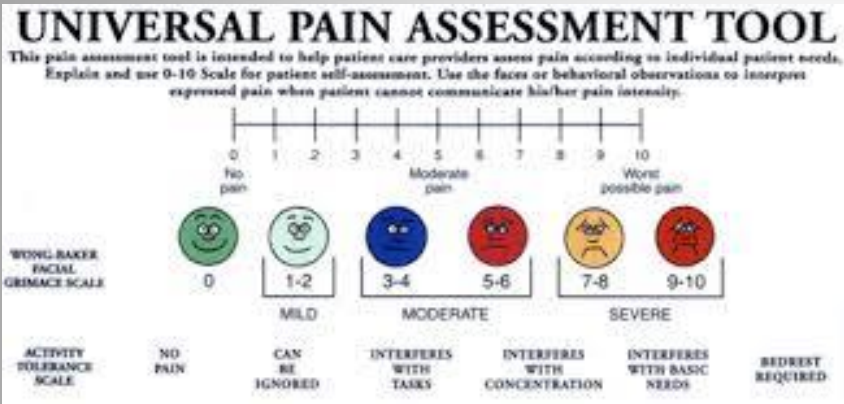
Reality and Challenges



Tomorrow

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

→ What about methods and systems?



Subjective evaluation based on scales, manually data record

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

Physical Therapy

Today and Tomorrow Clinics

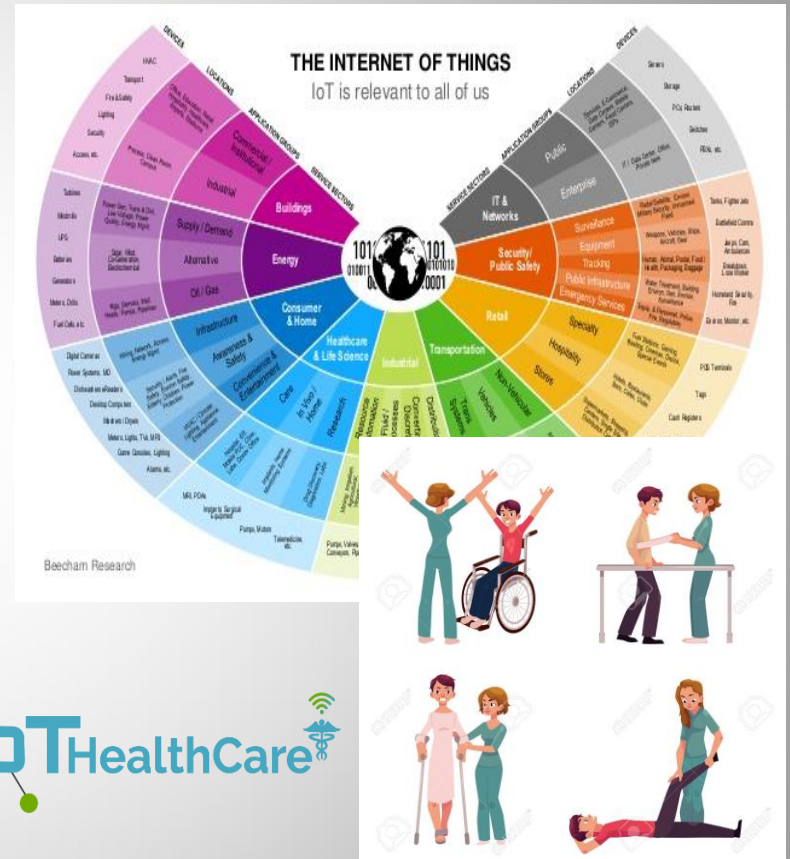


- Exclusively Usage of Mechanical Devices by the physiotherapists in Regular Clinics
- No Feedback for user or physiotherapists
- No Data Records or/and Internet Connectivity

How about IoT compatibility for tomorrow?

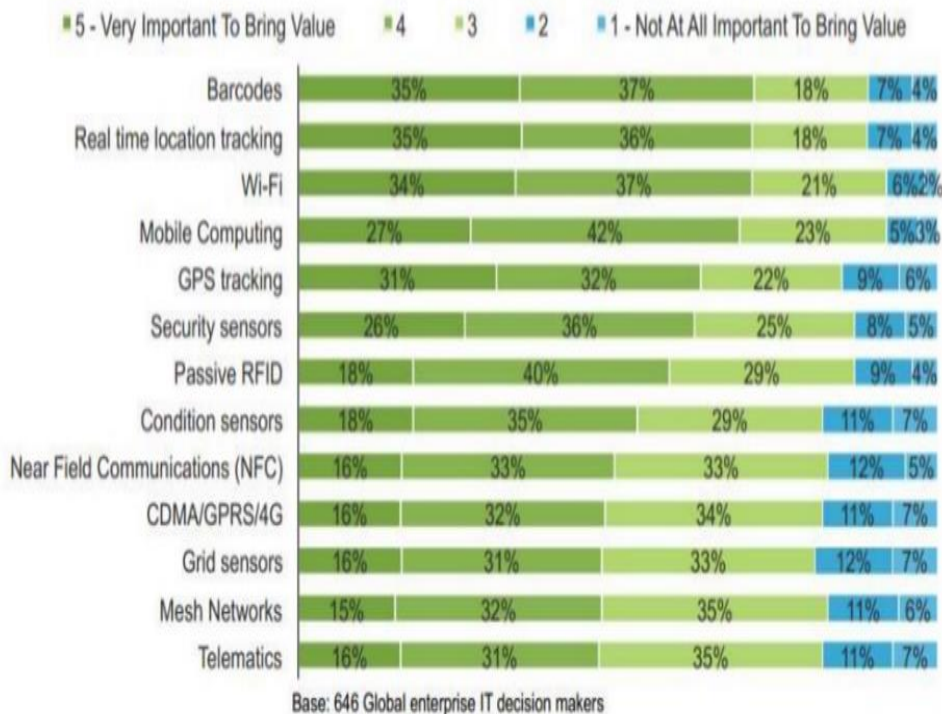
Technologies for Today and Tomorrow

- 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



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?

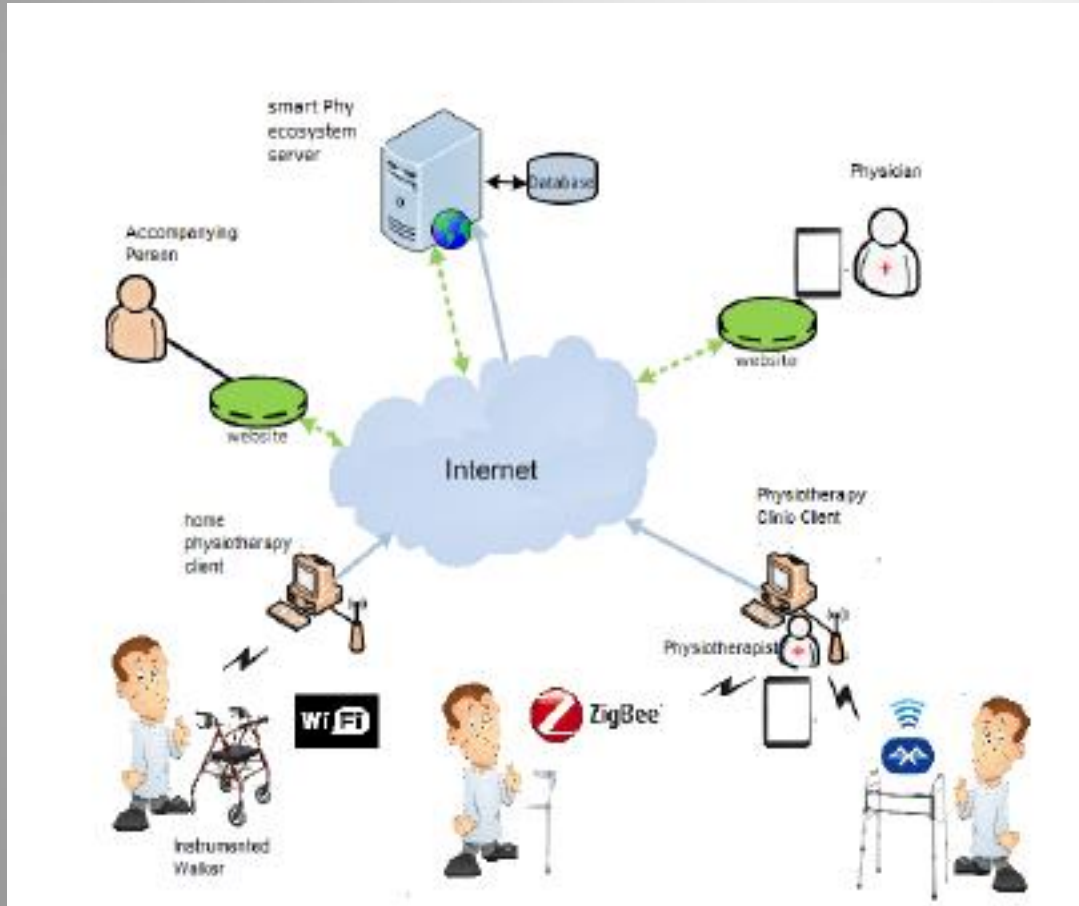
IoT technologies *for IoT Healthcare*



- 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?

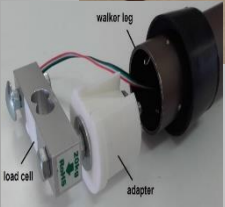
Smart Physiotherapy *Walking Aids Network for Gait Rehabilitation*



- 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



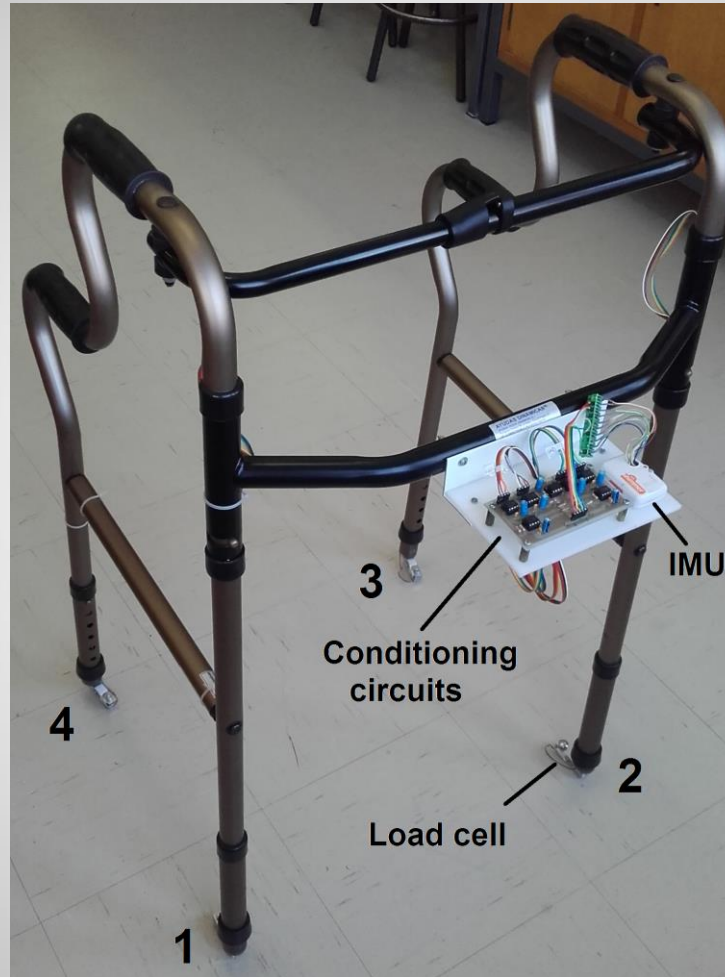
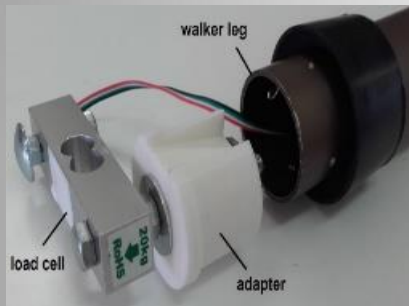
standardW

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*

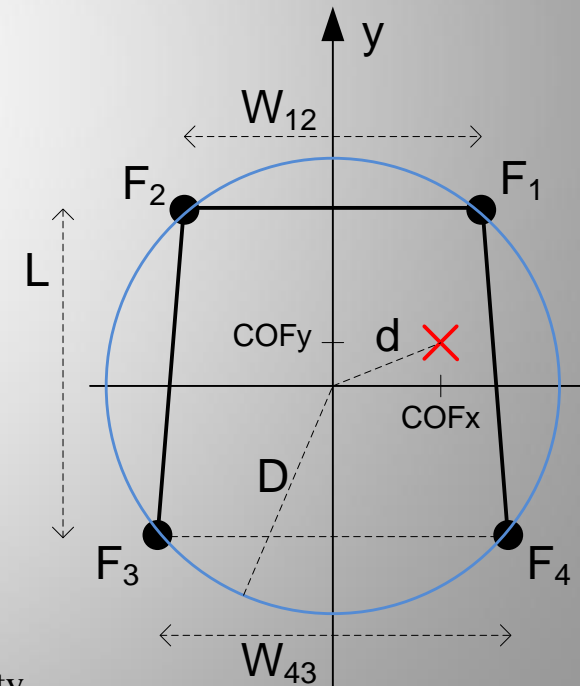
Walking Aids Net Nodes standardW prototype



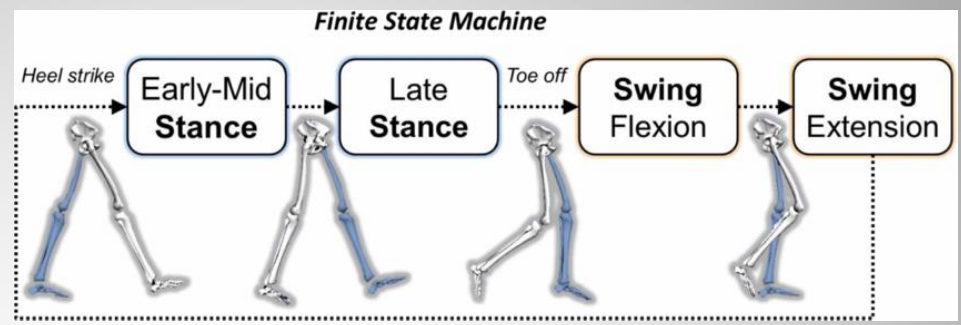
» Risk index (un)balance:

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

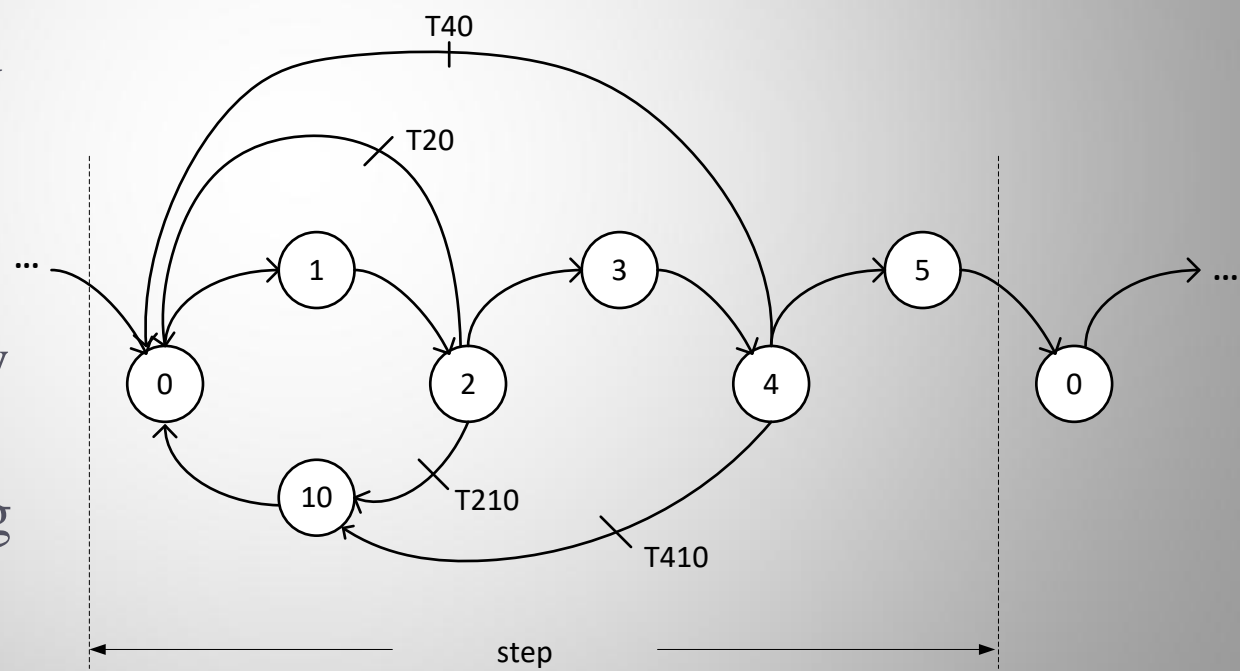
α : weighting factor



state machine for step classification



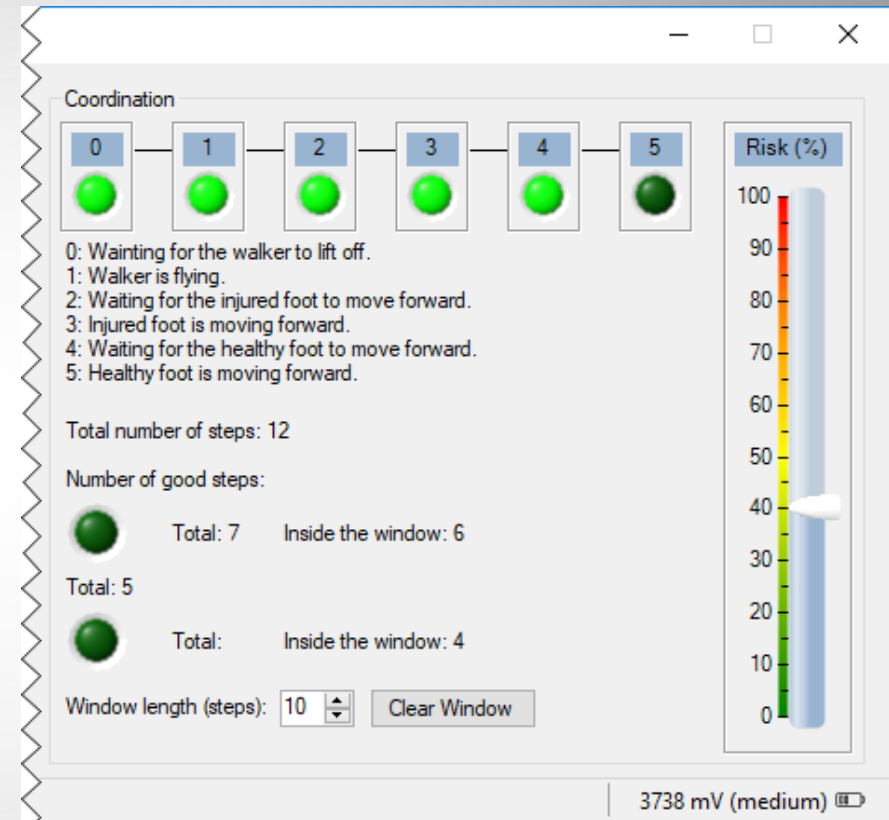
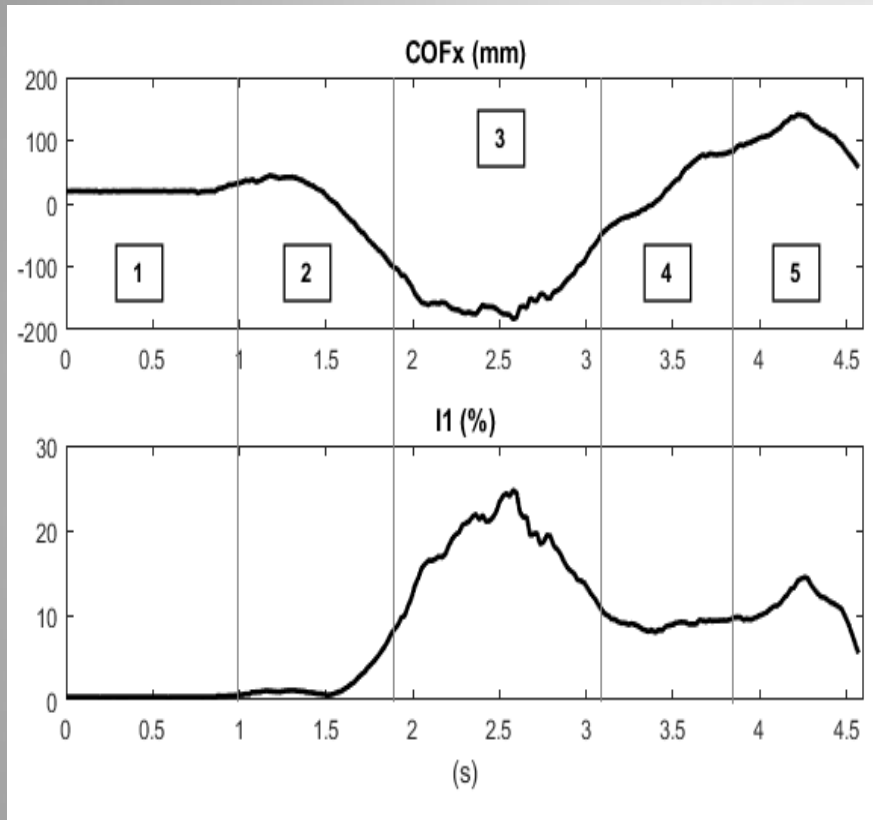
- 0: Waiting for the walker to lift off;
- 1: Walker is flying;
- 2: Waiting for the injured foot to move forward;
- 3: Injured foot is moving forward;
- 4: Waiting for the healthy foot to move forward;
- 5: Healthy foot is moving forward.



classified “correct” step → if the user completes all states from 0 to 5

The incoordination index I_2 is calculated.

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



(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

Coordination

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.

Total number of steps: 12

Number of good steps:

● Total: 7 Inside the window: 6

● Total: 5 Inside the window: 4

Window length (steps): 10 Clear Window

Risk (%)

3738 mV (medium)



Spy Walker : Stream Data

Balance

Center of Forces

Y (cm)

X (cm)

Risk (%)

Coordination

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.

Total number of steps: 3

Number of good steps:

● Total: Inside the window: 0

● Total: 3 Inside the window: 3

Window length (steps): 10 Clear Window

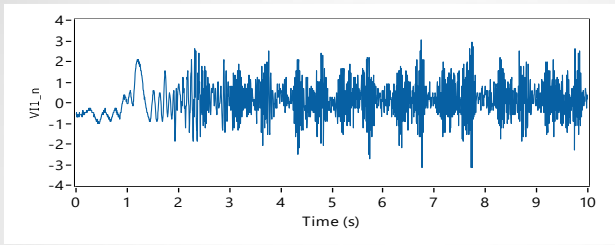
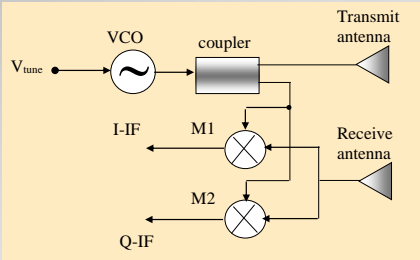
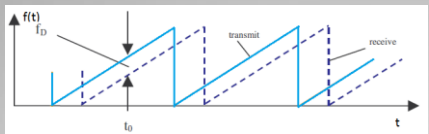
Risk (%)

Step completed: quality = BAD; failure = STEP_ABORTED.

3792 mV (medium)

Walking Aids Net Nodes

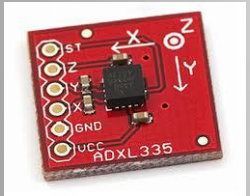
2wheelsW prototype



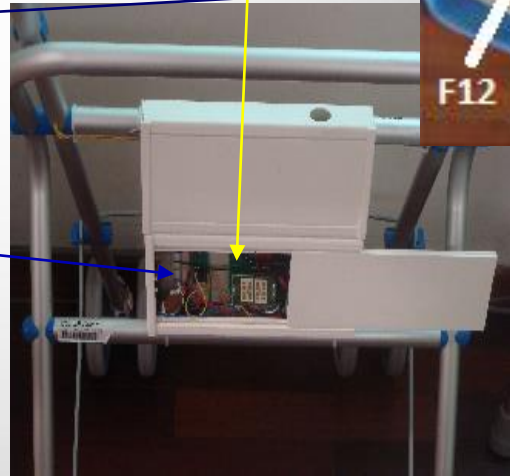
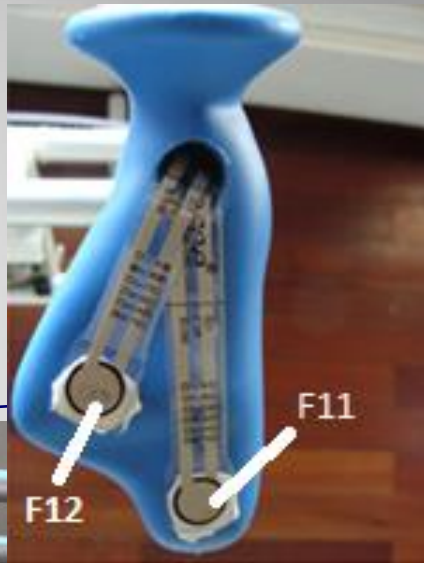
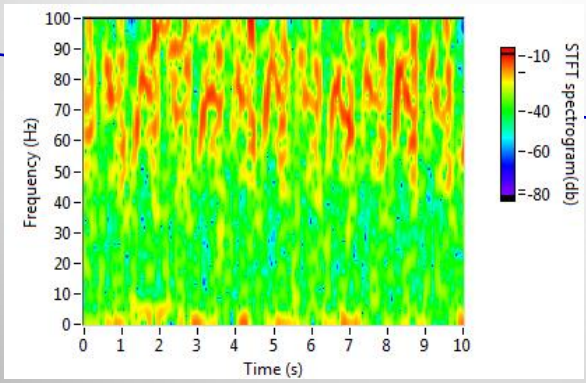
Single
Doppler
Radar



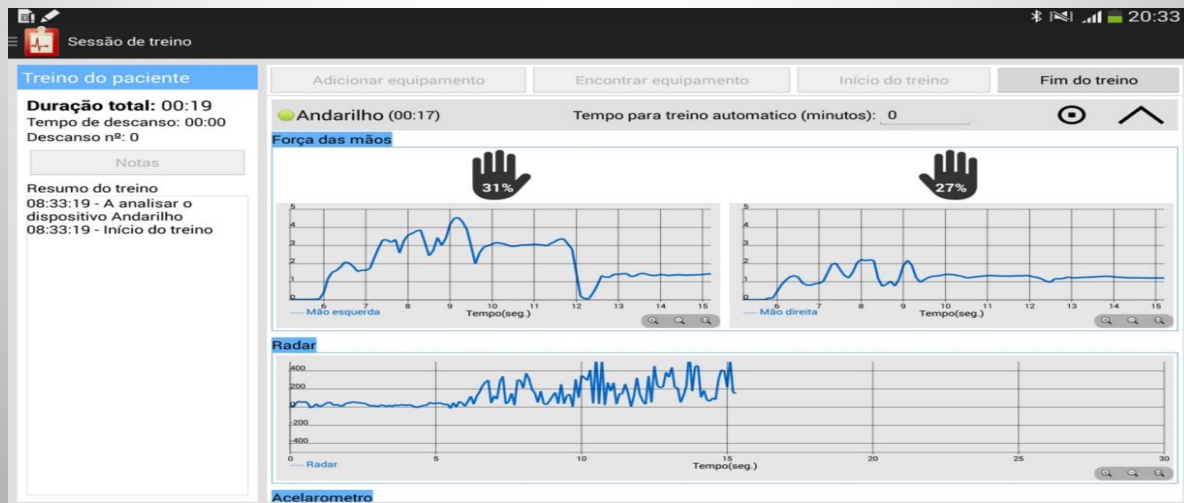
Force
sensor



3D
accelerometer

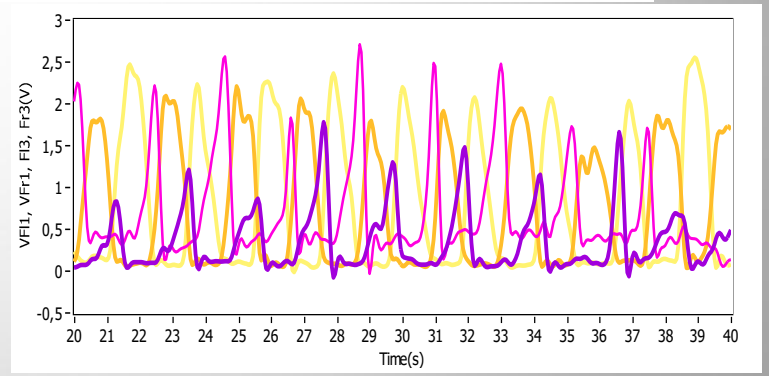
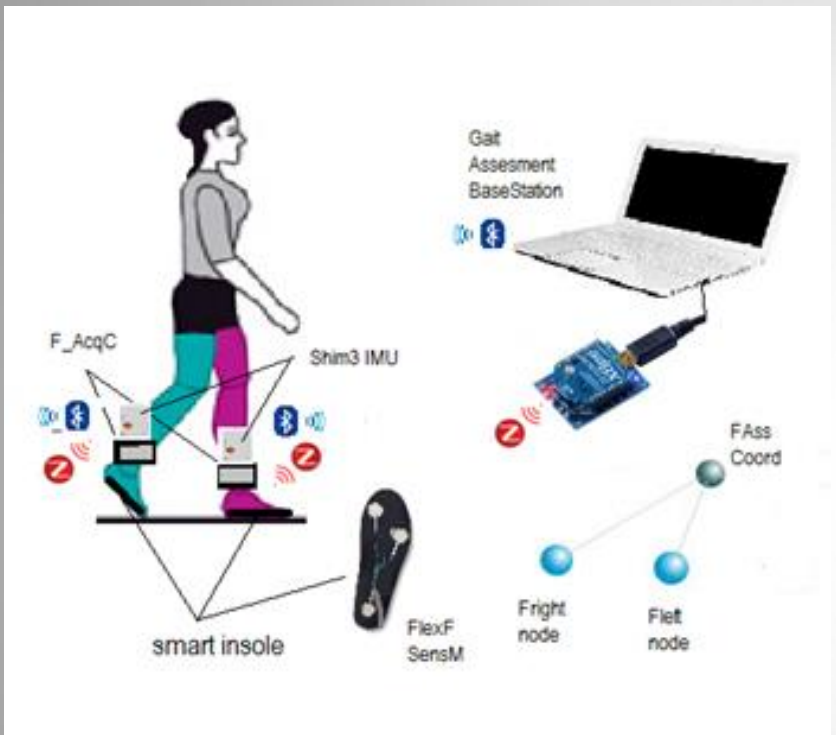


Walking Aids Net Nodes 2wheelsW mobile software



Wearable Gait Rehabilitation

Smart Insole based PRS



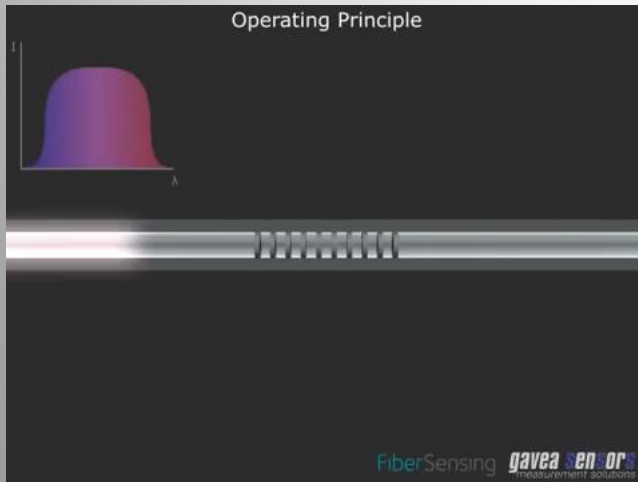
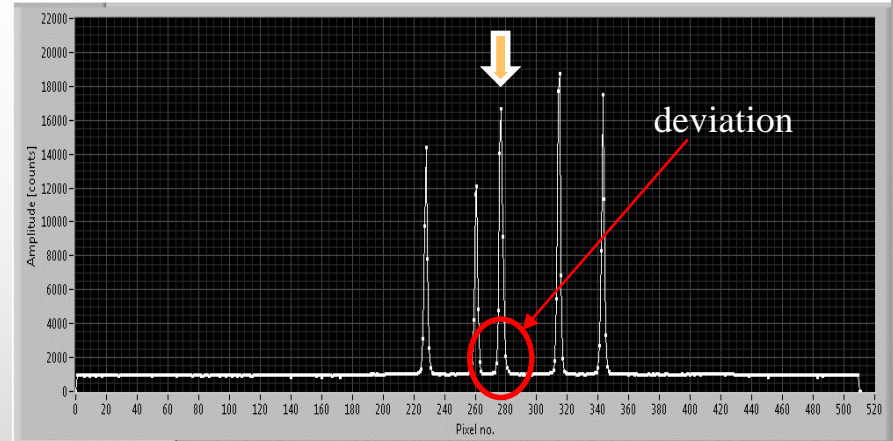
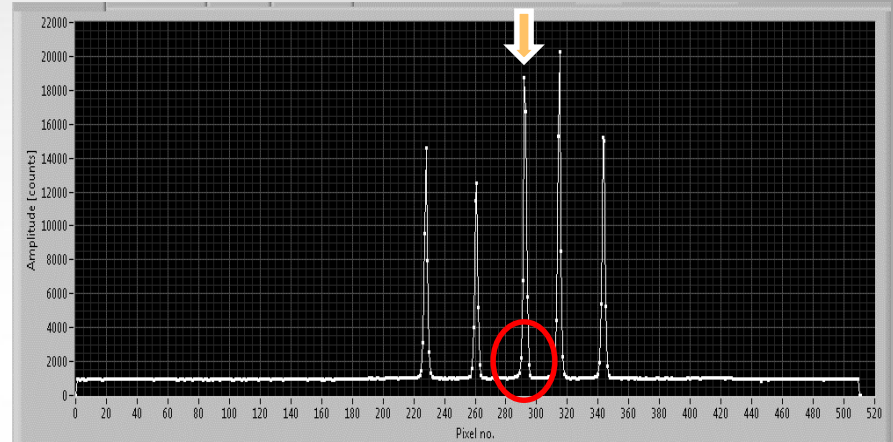
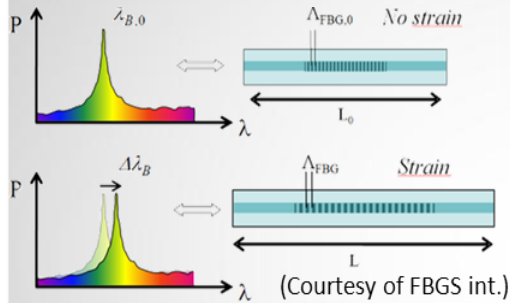
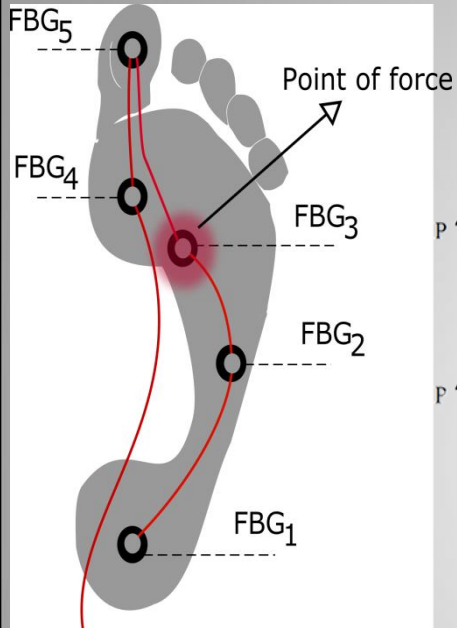
voltage signals normal gait from metatarsal calcaneus area

ATEE 2015, Bucharest, Romania

Wearable Gait Rehabilitation

Smart Insole based on FBG array

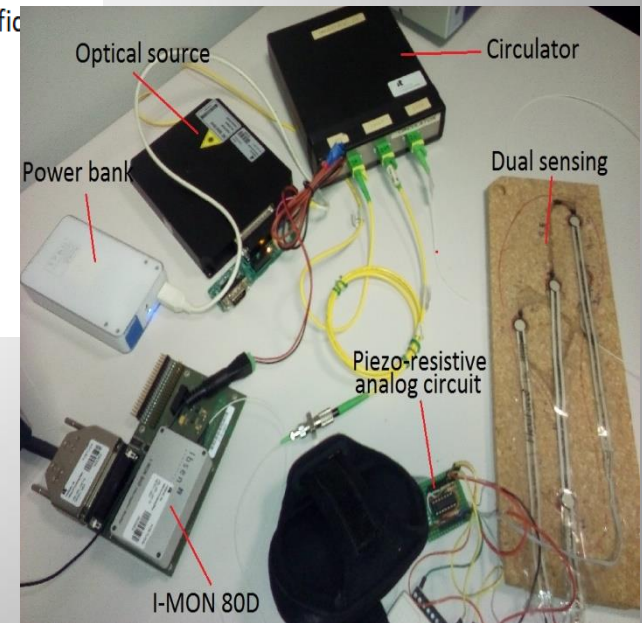
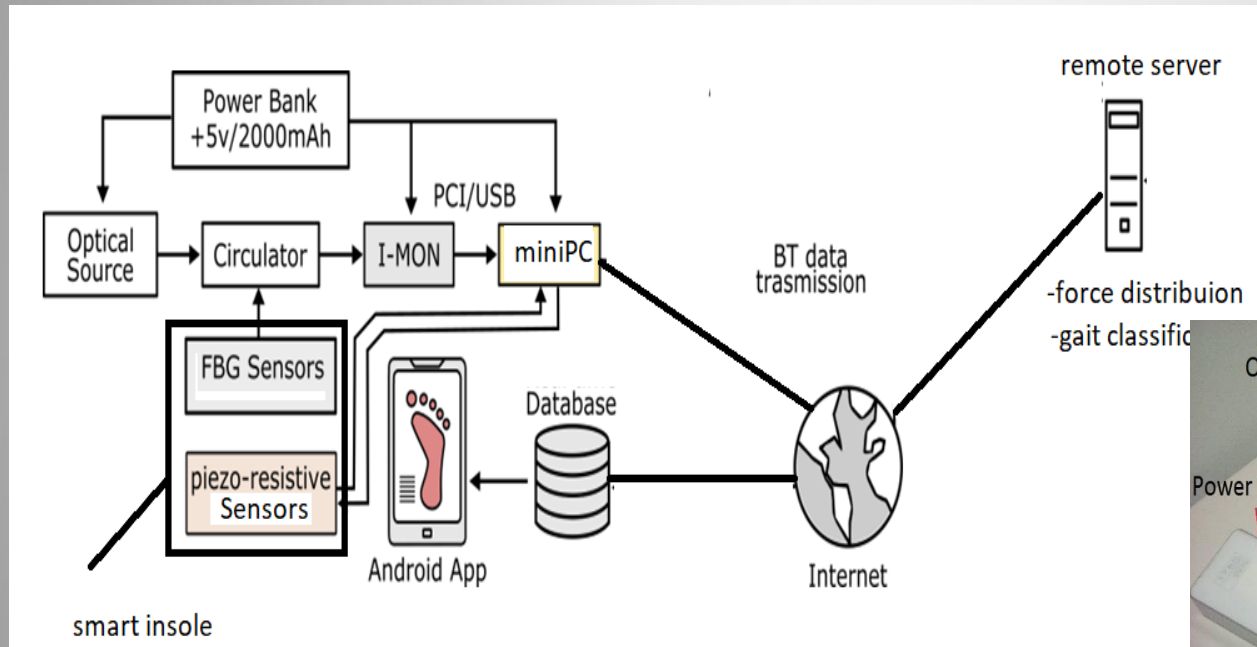
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Wearable Gait Rehabilitation

Smart Insole based on FBG array

- The Fiber Bragg Gratings Architecture



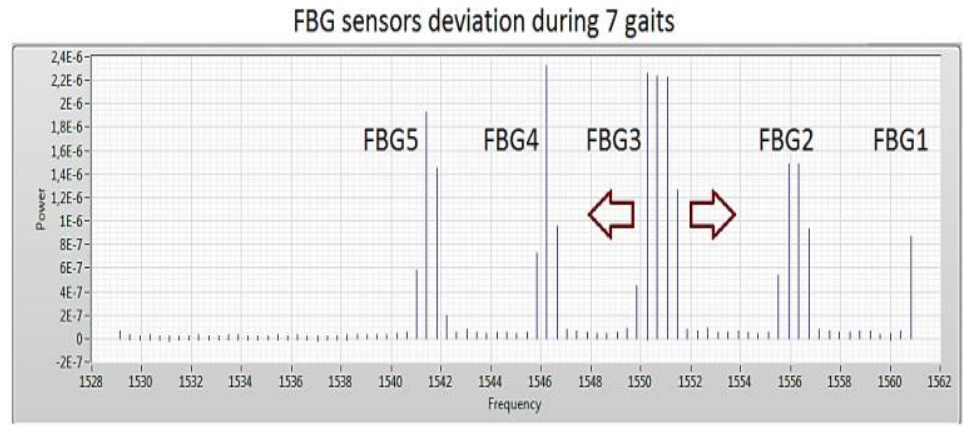
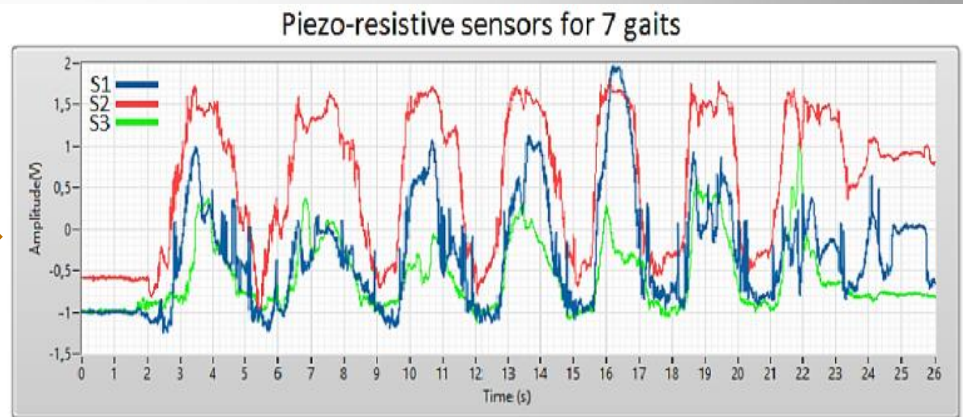
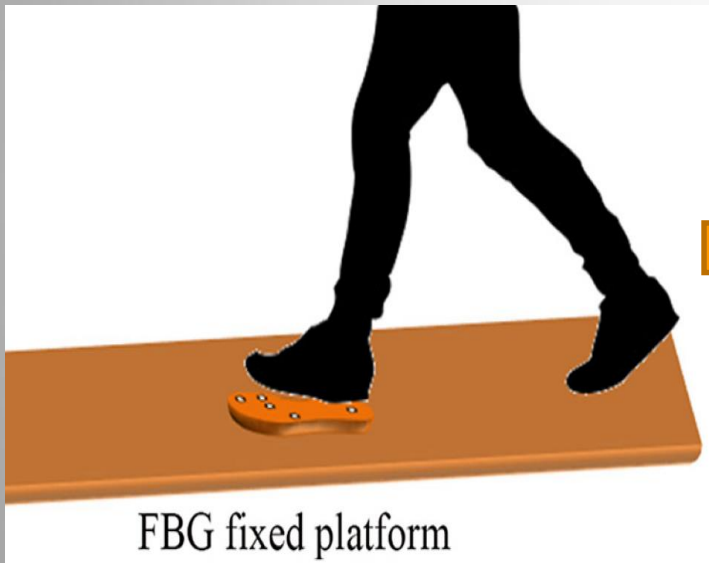
- Insole Fiber Bragg Grating (FGB) Network prototype
 - Were used 5 t o 6 FBGs
 - Force measurement using PRS Tekscan A201

Wearable Gait Rehabilitation

Smart Insole based on FBG array

Smart Insole Comparative Results

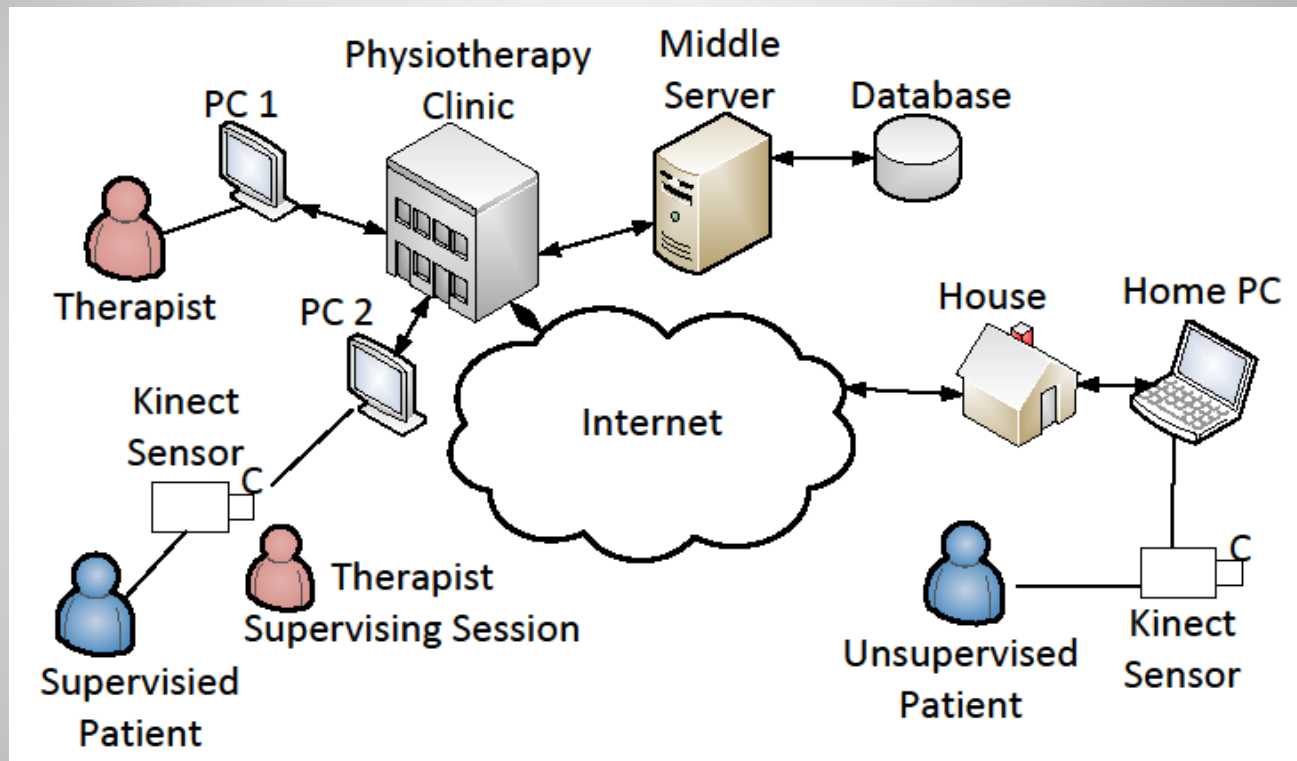
piezo-resistive sensors with FBGs sensor network



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

Remote sensing and IoT for smart physiotherapy

Kinect Computation Architecture

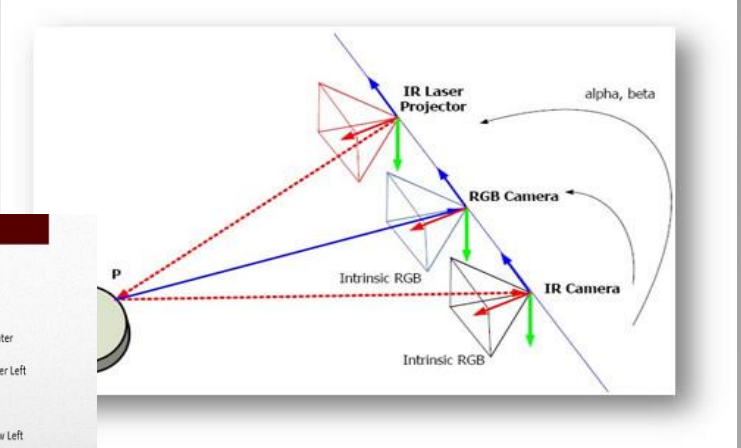
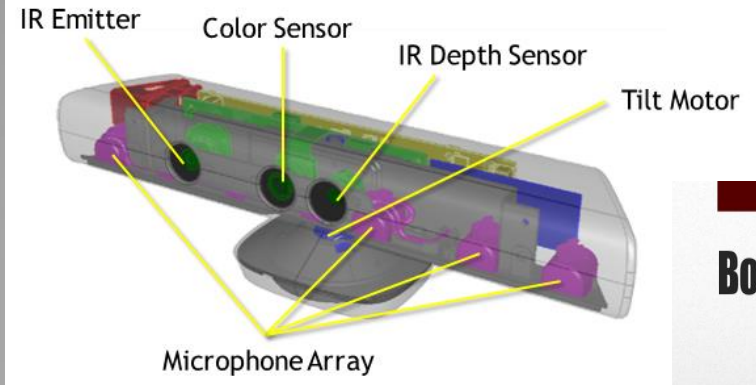


Kinect Serious Games on the client side are
GRANTED

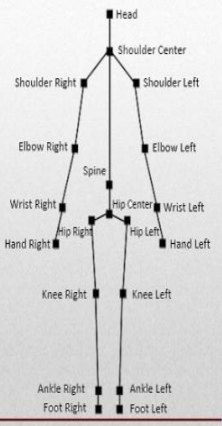
Unobtrusive sensing of physical rehabilitation

Kinect sensor

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Body Joints



IR speckle pattern



Depth estimation

20 body joints SDK

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



- **Therasoup**,



- **AppleHarvesting**



- **JustPhysioKidding**

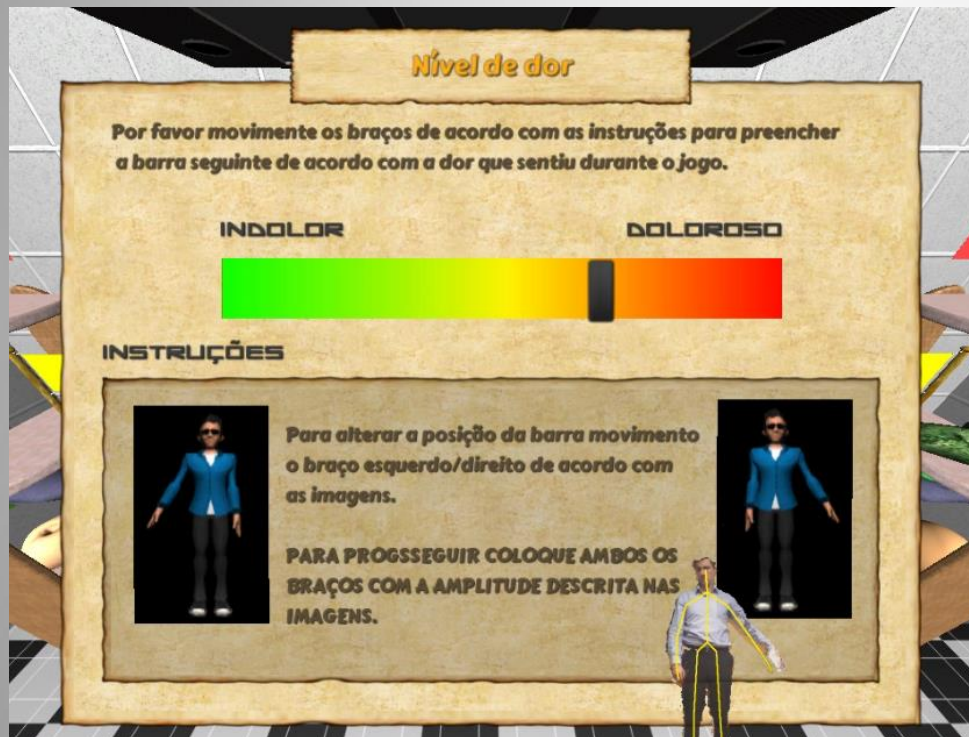
Kinect Serious Games For Rehabilitation *Therasoup v2.0*



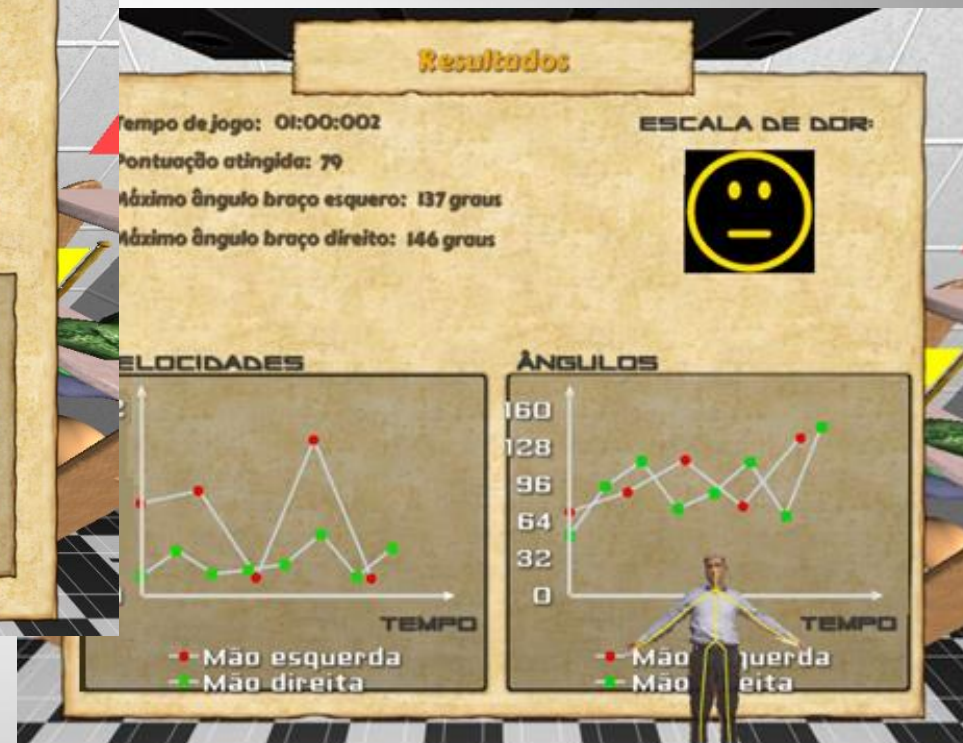
Unity 3D and C# technologies were used to develop the game

“Therasoup” Kinect Serious Games *training metrics and pain scale*

Pain scale game GUI



Training outputs





Physio EHR Hello, admin! [Log off](#)

[Admin](#) [Home](#) [Patient Analysis](#) [About](#) [Contact](#)

Patient Analysis.

Patient Personal Info:

Francisco Cary
User: patient
Card ID: 12345
Email: fcary.fc@gmail.com

Rehabilitation Sesseion Parameters

Maximum right arm abduction:
Maximum right arm extension:
Maximum left arm abduction:
Maximum left arm extension:

Session Data

Choose Session

Pain And Score History Over The Previous Sessions

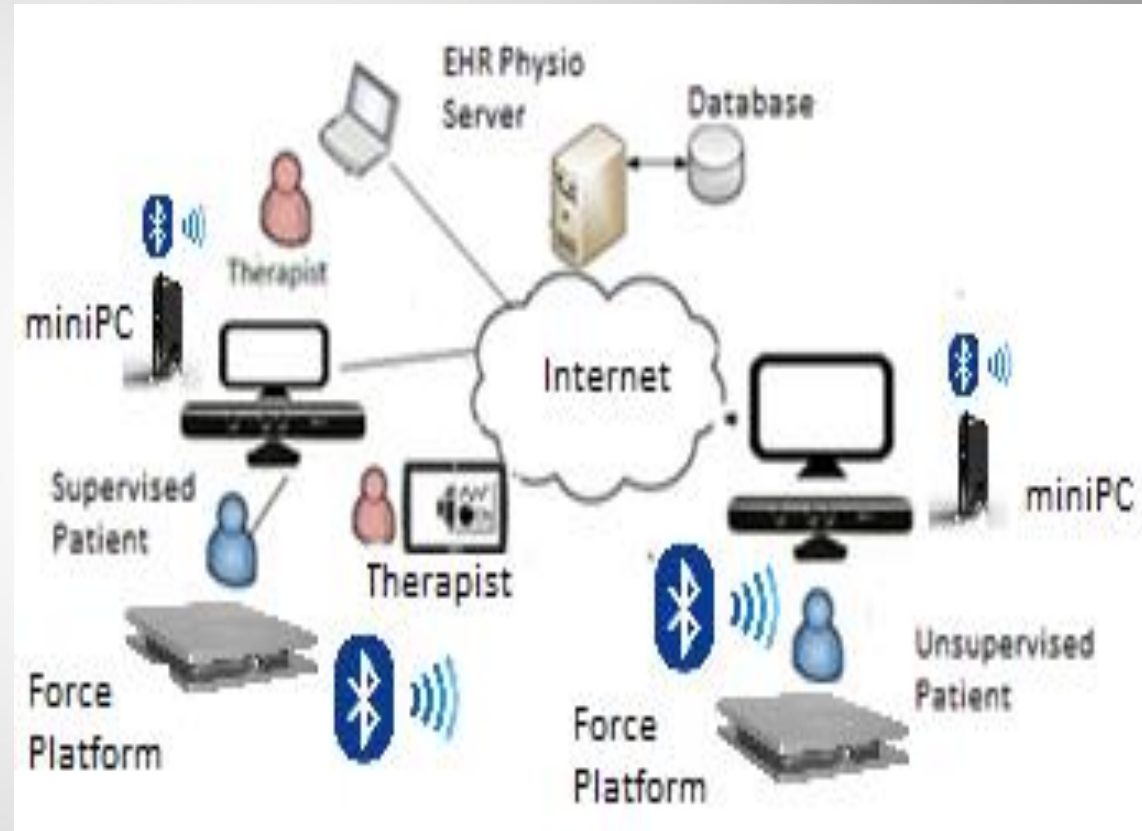
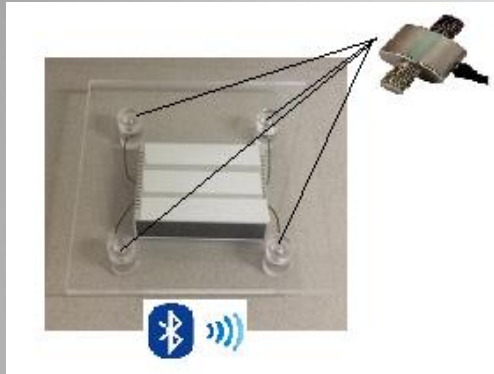
■ Game Score ■ Pain Score

Session	Game Score	Pain Score
08/19/2014 17:44:26	~100	~1.00
08/19/2014 17:46:20	~400	~0.90
08/19/2014 17:48:13	~200	~0.80
08/19/2014 17:53:17	~550	~0.55
08/19/2014 17:54:54	~500	~0.35



*web based: game configurator
game score and pain assessment*

Smart Physiotherapy Tailored Environments *Kinect & Force Platform*



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

Gaming Tests

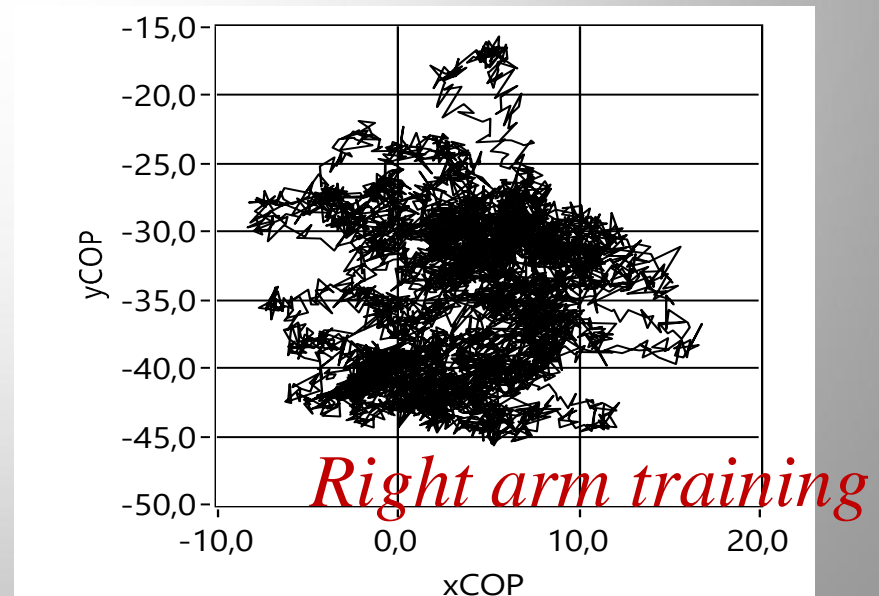
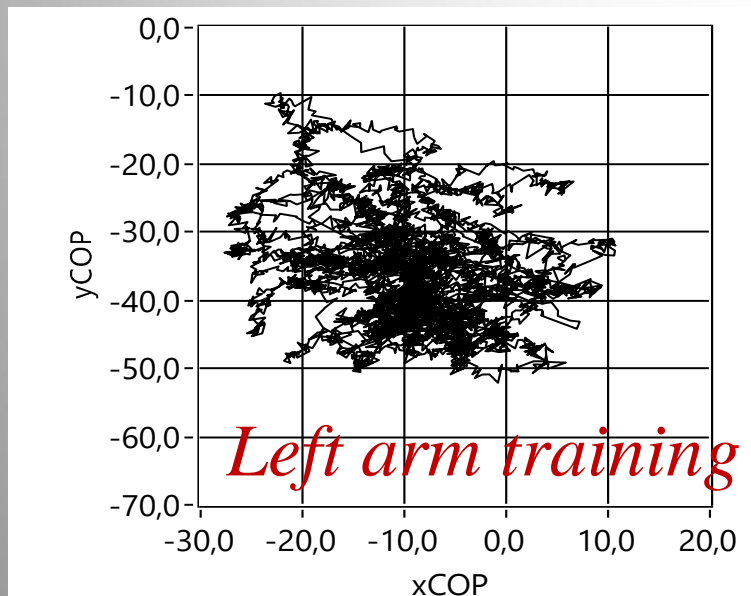
COP amplitudes



subject	metrics	L game (mm)	R-game (mm)	L-R (mm)	game
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	

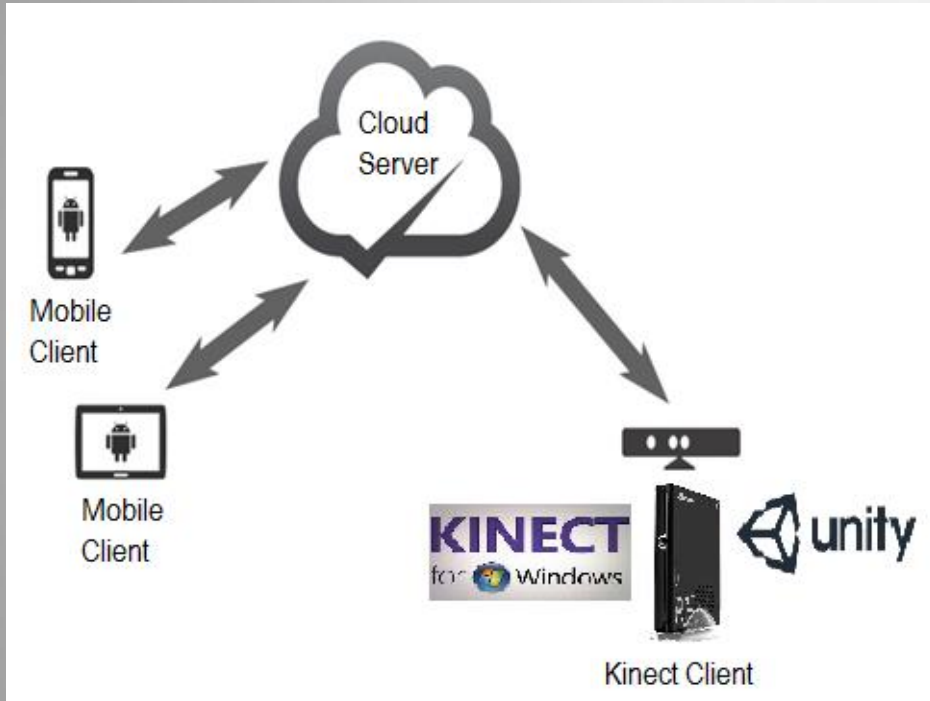
Amplitudes

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

Kinect Serious Games For Rehabilitation

Objective Evaluation results on APP interface



Manuel Santos
manuelsantos@gmail.com
problema no joelho esquerdo

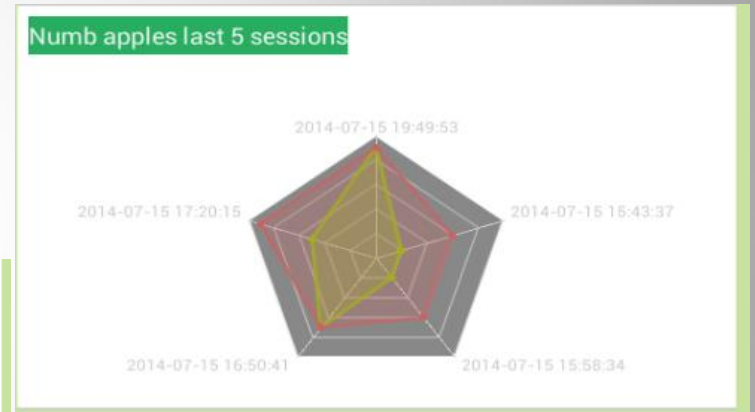
Add Plan

Plans
x3

Notes
x2

Goals
x10

Stats
x55



Game stats

Green Apples: 2
Red Apples: 6
Total Apples: 8
Points: 700

Kinect Serious Game for Rehabilitation

Tailoring "Apple Harvesting"

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Tempo
0:29

Resultados

Bom trabalho!

Conseguiu **2700** pontos.

Apanhou **40** maçãs.

Maçãs verdes: **26**

Maçãs vermelhas: **14**

Conseguiu apanhar maçãs nestes ângulos:

70 graus: Esq. 0 (0 0) | Dir. 7 (4 3)

85 graus: Esq. 21 (15 6) | Dir. 8 (6 2)

100 graus: Esq. 4 (1 3) | Dir. 0 (0 0)



Kinect Serious Game for Rehabilitation

Tailoring “Apple Harvesting” Stroke – hand rehab phase I

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Kinect Serious Game for Rehabilitation

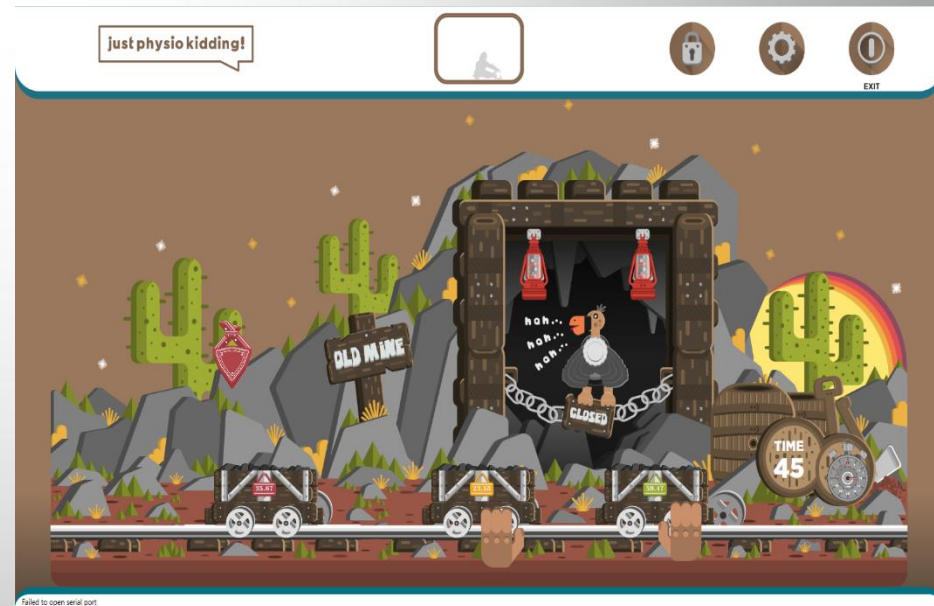
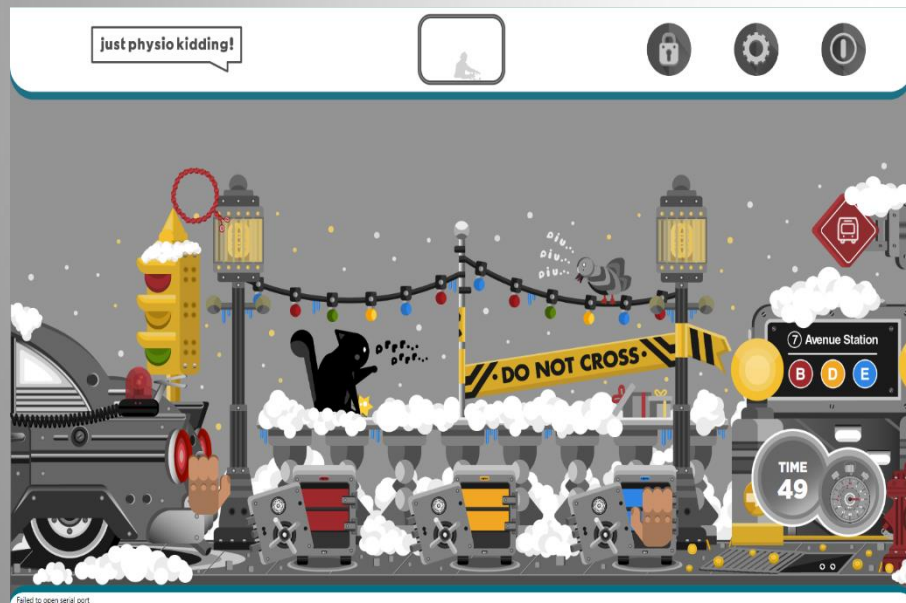
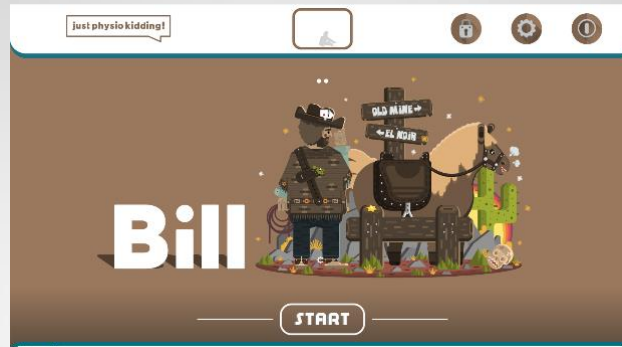
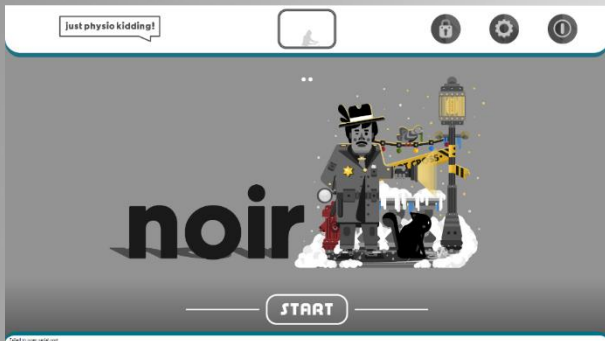
Tailoring “Apple Harvesting” Stroke Phase rehab phase II

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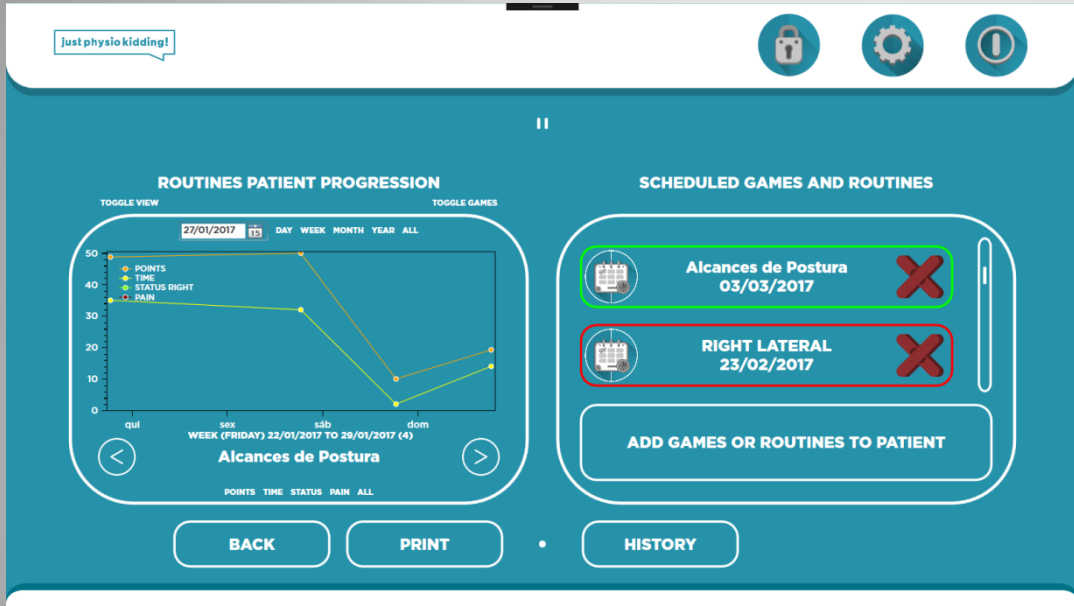
Kinect Serious Games For Rehabilitation *Cerebral Palsy*

*JustPhysioKidding
Gaming Scenarios*



Kinect Serious Games For Rehabilitation

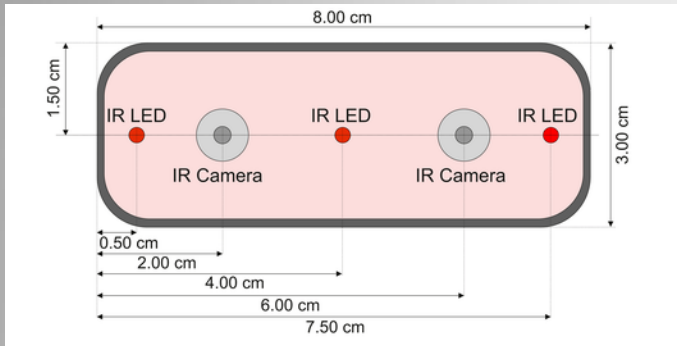
JustPhysioKidding



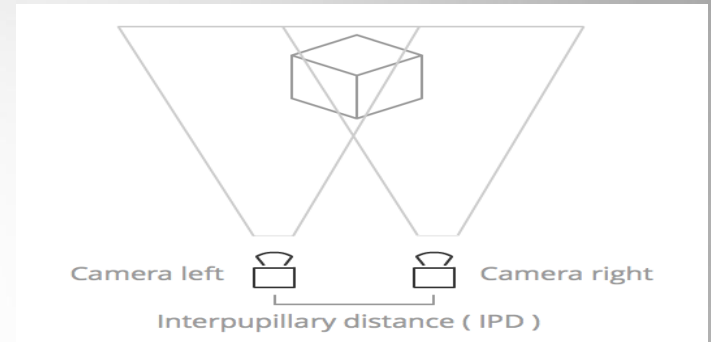
*Results GUI
Plan and Motion
Reconstruction*

Serious Game for Physical Rehabilitation

Leap Motion Controller



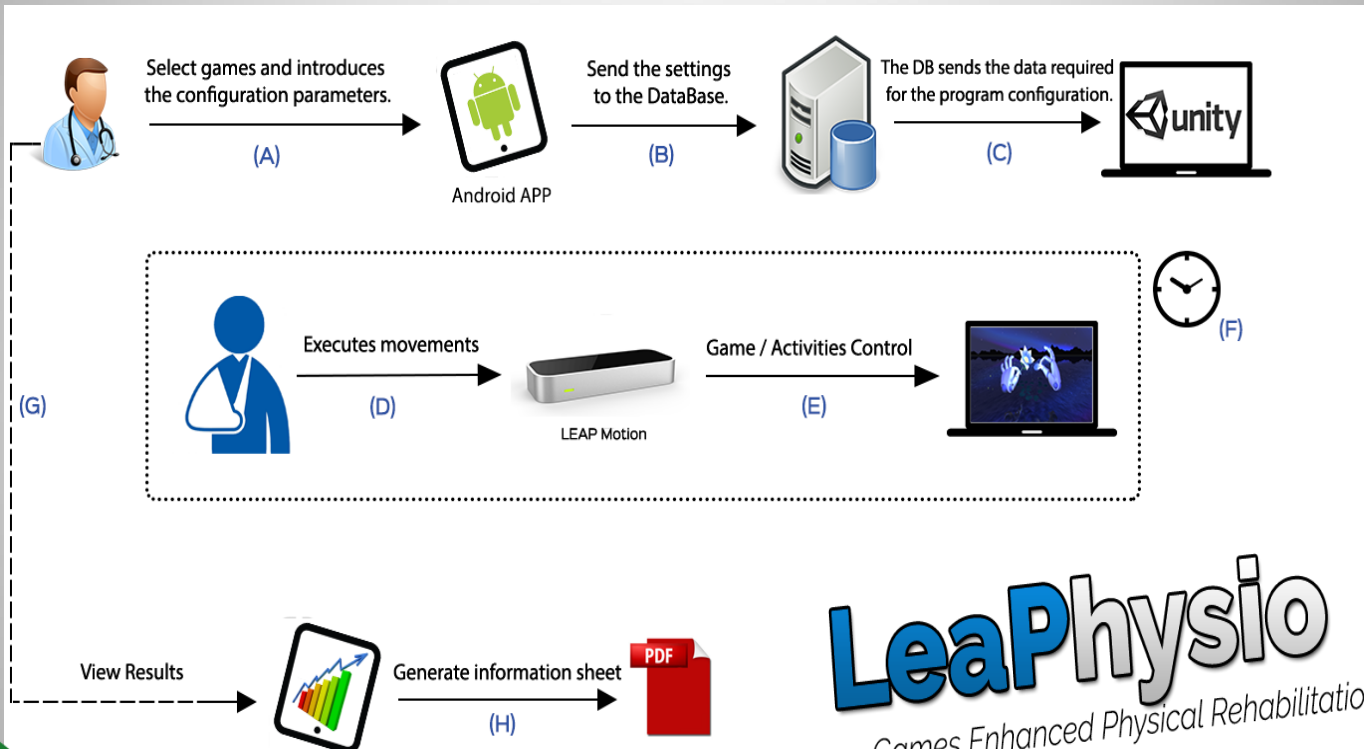
- **two cameras** track infrared light produced by three infrared LEDs.



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

Serious Game for Physical Rehabilitation

Leap Motion - Serious Game Platform

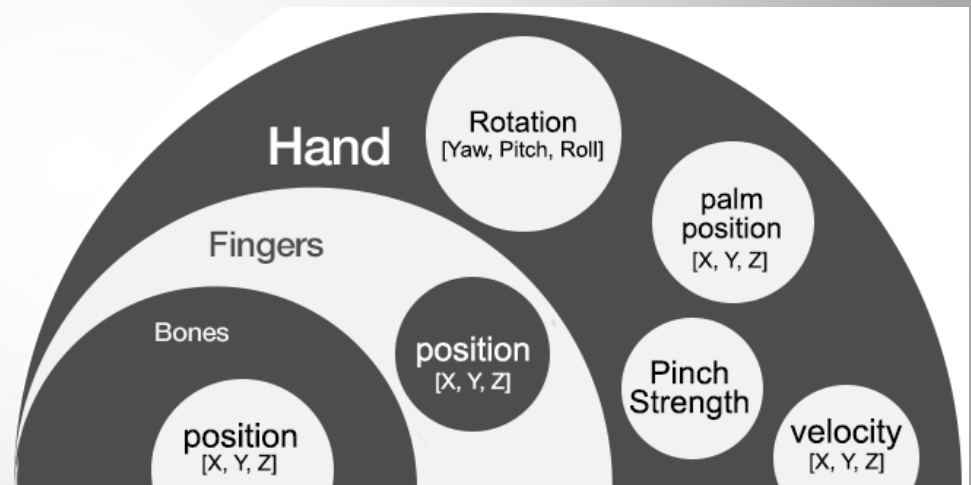


LeaPhysio
Games Enhanced Physical Rehabilitation



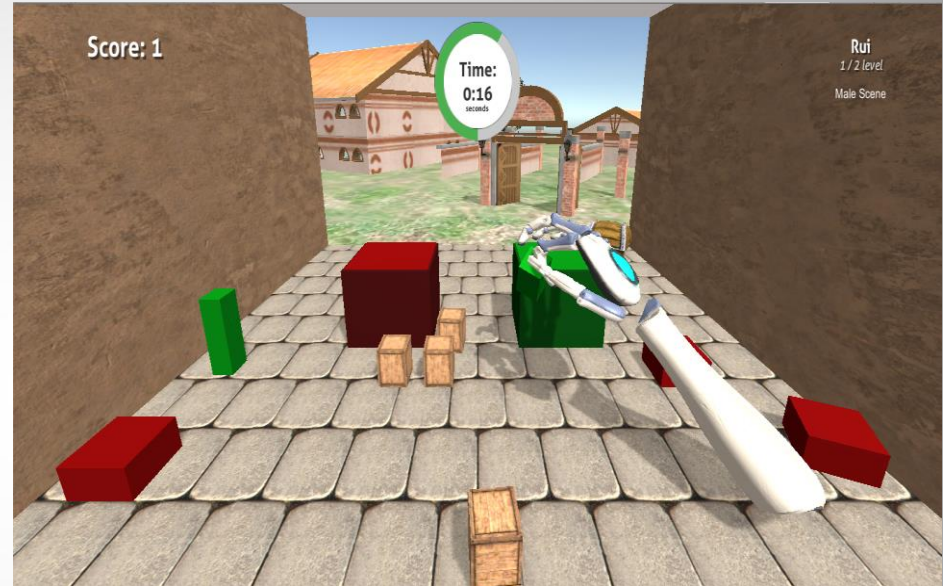
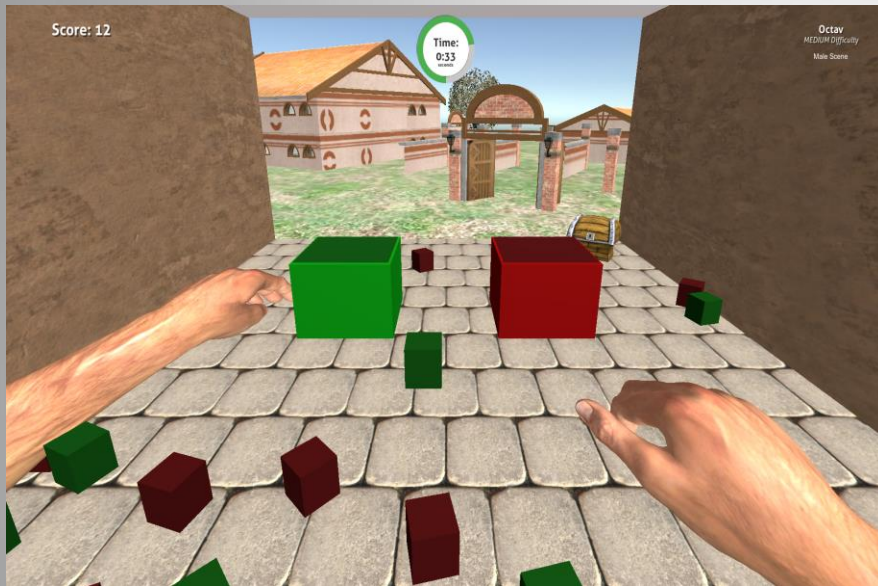
Serious Game for Physical Rehabilitation

Leap Motion - Serious Game Platform



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

➤ 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

➤ Game: Collect Cube

- **THEME: OBJECTS**



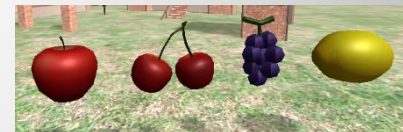
- **CUBES**



Sports



Animals



Fruits

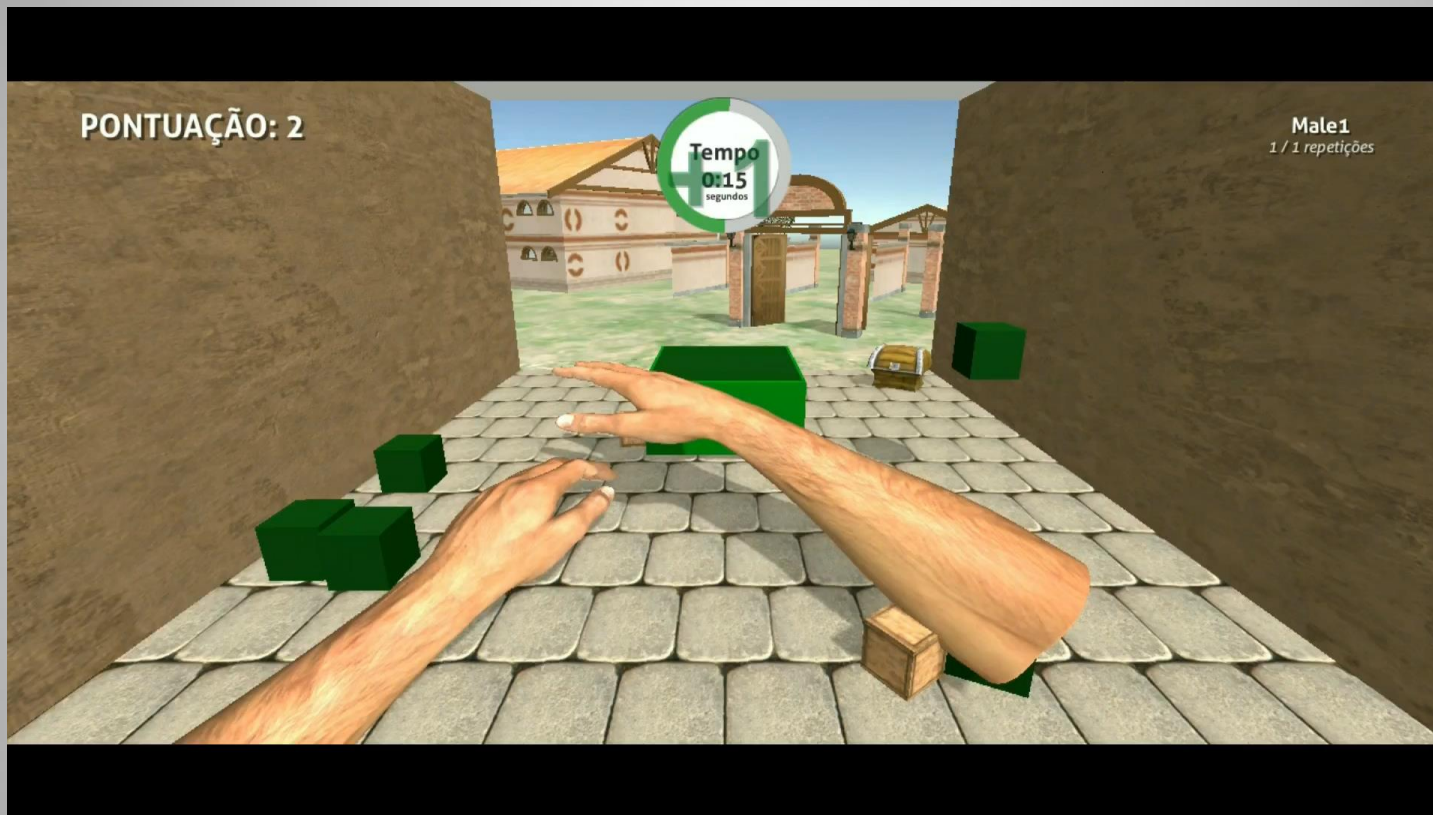
- **BOXES**



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



Game: Collect Cube

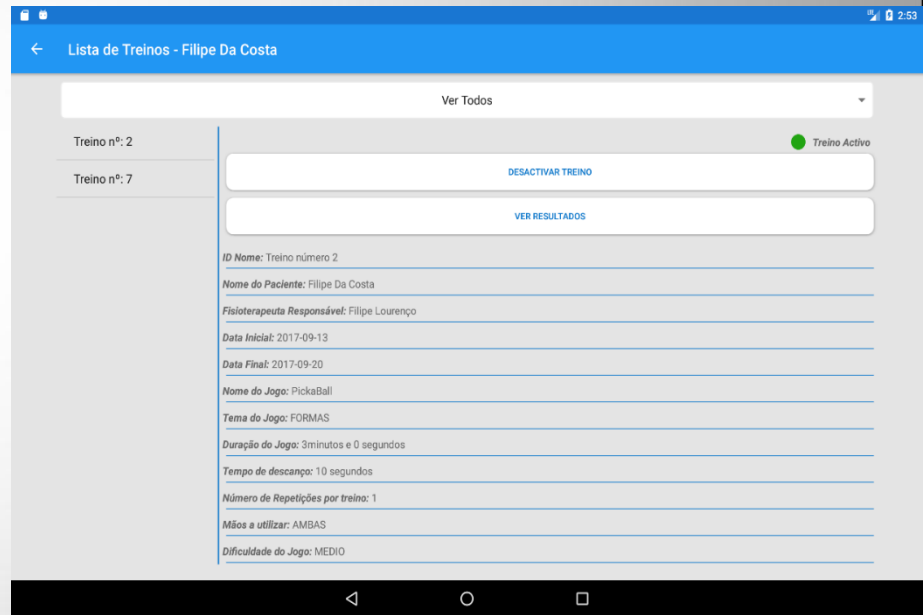
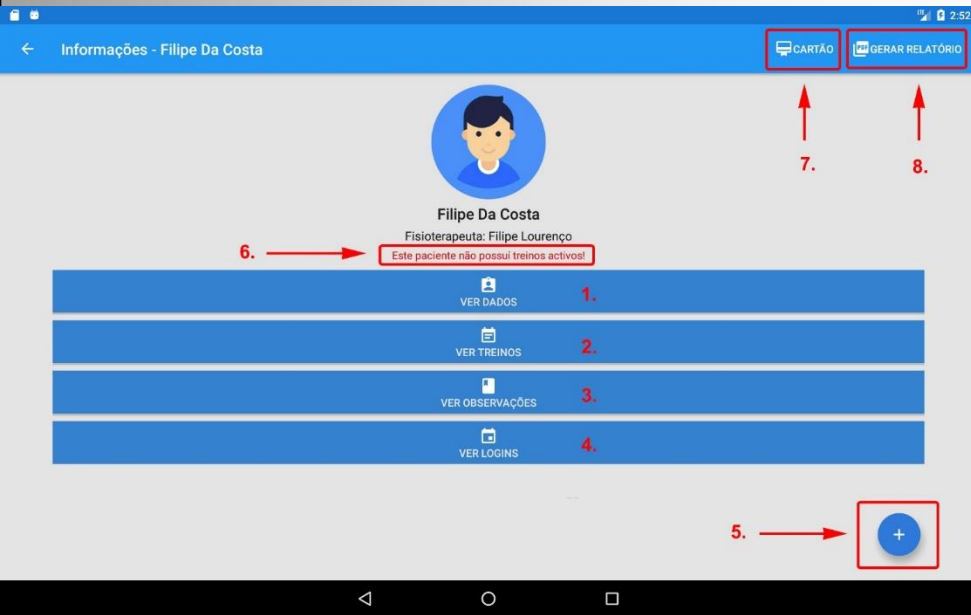


- Motor and cognitive rehabilitation together



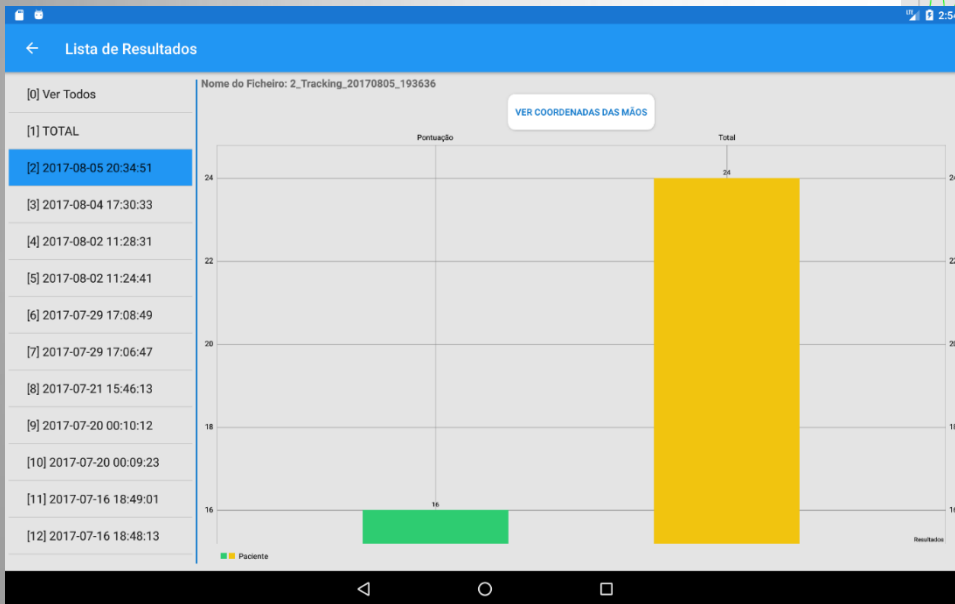
LeaPhysio

Games Enhanced Physical Rehabilitation



*user and training plan
records*

Score and joint position *by date*



Infrared Thermography for Physical Therapy

Objective evaluation of muscular activity



Infrared Thermography: Every object whose surface temperature is above absolute zero ($-273\text{ }^{\circ}\text{C}$) radiates energy at a wavelength (short wave $3\text{-}5\mu\text{m}$ and long wave $7\text{-}9\mu\text{m}$) corresponding to its surface temperature.



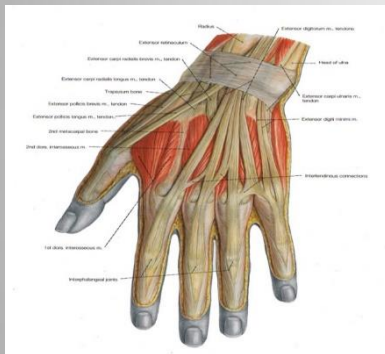
To obtain **Thermographic Image** highly sensitive (0.05°C) infrared camera (e.g. FLIR E60) capture thermal radiated energy with good accuracy (error 2% of reading).

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

Infrared Thermography for Physical Therapy

Unobtrusive sensing of muscular activity

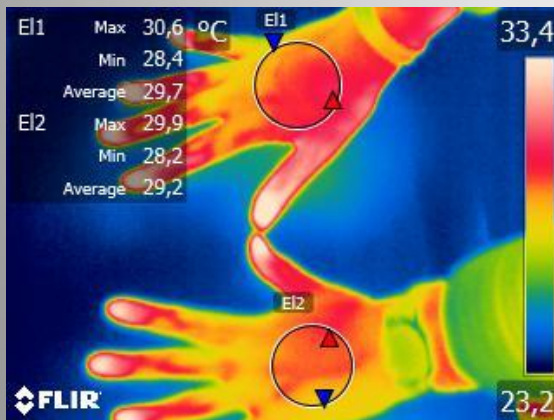
IEEE
INSTRUMENTATION
& MEASUREMENT
SOCIETY



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



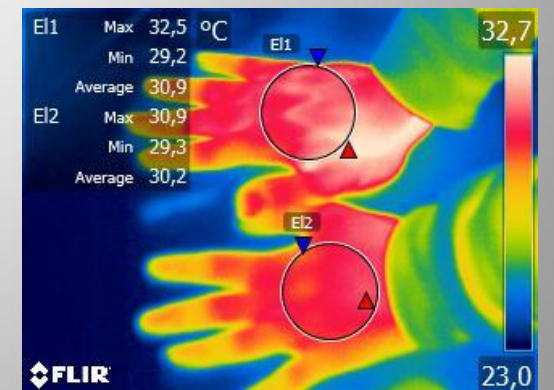
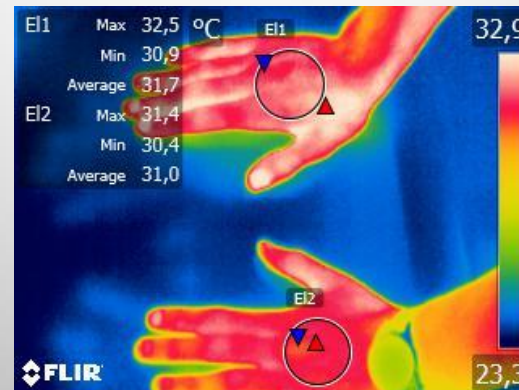
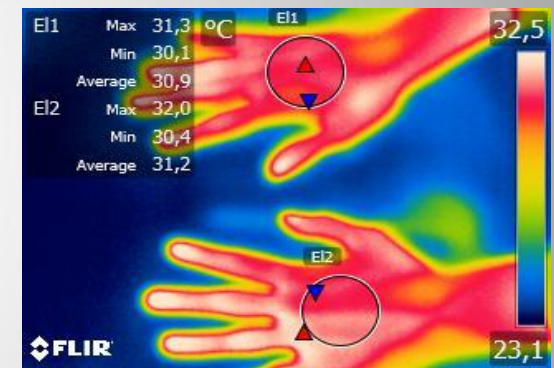
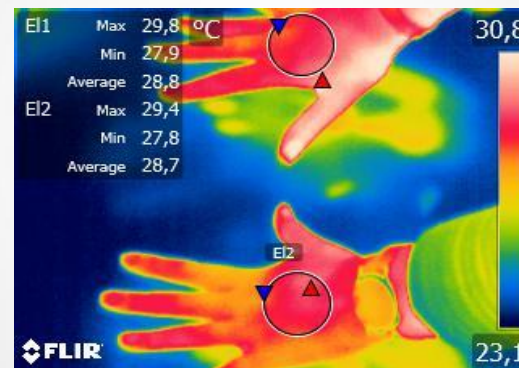
VR versus Real Scenario Serious game

Training Effectiveness Tests & Results

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

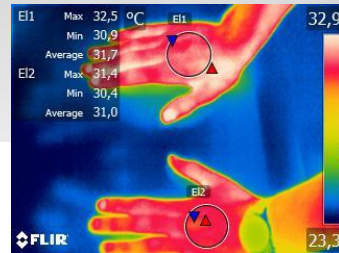
4 volunteers, 4 tests (0.5min, 1 min, 1.5 min, 2min)

→ *Thermographic images*



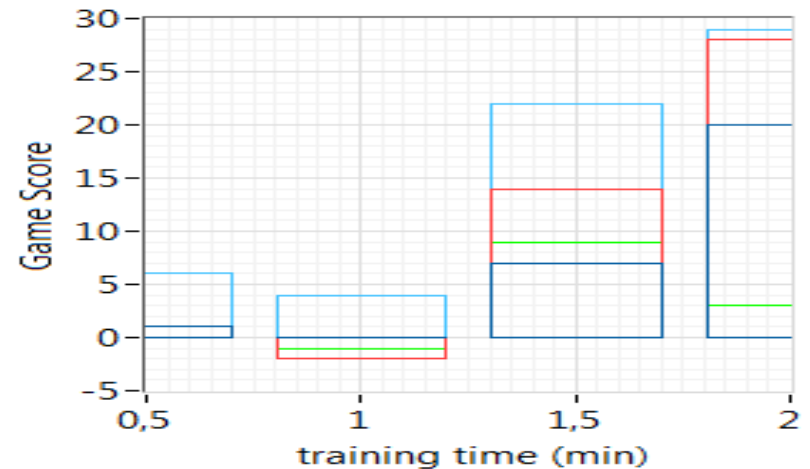
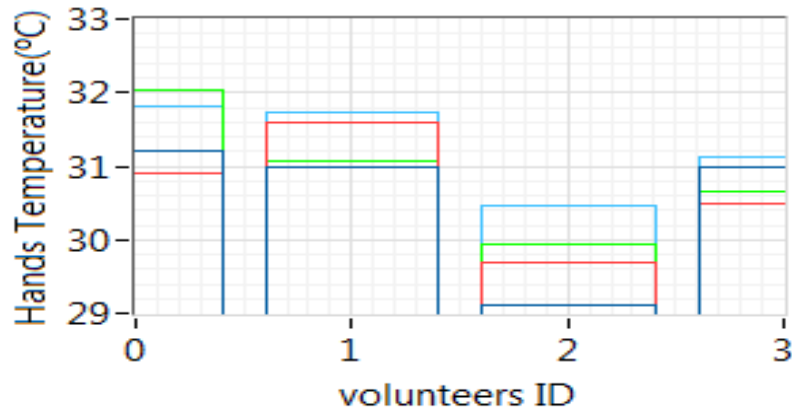
Infrared Thermography for Physical Therapy

Unobtrusive sensing of muscular activity



LeftHb
RightHb
LeftHa
RightHa

ID1
ID2
ID3
ID4

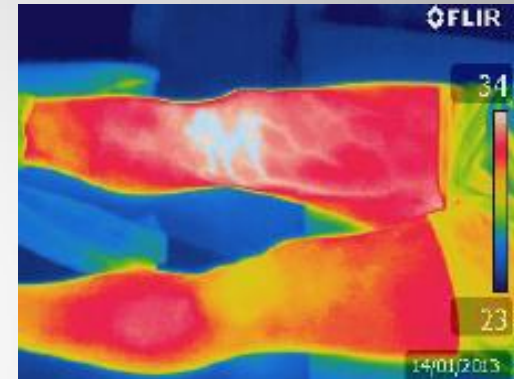
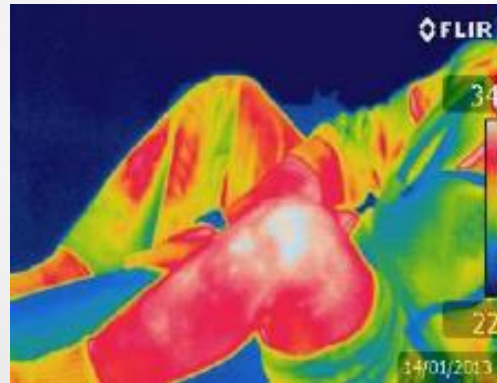


Average temperature evolution of hand skin temperature before and after 2 min training

Score Evolution for different training durations (IDi volunteer ID)

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.

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.**

IoT Symposium

The screenshot shows a web browser window displaying the IEEE Instrumentation & Measurement Society website. The browser's address bar shows the URL: ieee-ims.org/conferences/2018-international-symposium-sensing-and-instrumentation-iot-era. The website header includes navigation links for IEEE.org, IEEE Xplore Digital Library, IEEE Standards, IEEE Spectrum, and More Sites, along with social media icons for email, LinkedIn, Facebook, and Twitter. The main navigation menu contains links for Home, About IMS, Awards, Conferences, Education, Membership, Publications, and Technical Committees. The current page is titled "2018 International Symposium in Sensing and Instrumentation in IoT Era" and provides the following information:
URL: <http://issi2018.csp.escience.cn/>
General Chair(s): Yongsheng Yang, Octavian Postolache, Xin Wang
Conference Date: 2018-09-06 to 2018-09-07
Initial Submission Deadline: 2018-06-01
Program Chair(s): Dong Wang, Subhas Mukhopadhyay, Domenico Capriglione, Daqi Zhu, Chaofeng LI
On the right side of the page, there is an advertisement for a free book titled "Guide to Publishing Your Research" with a "Click Here" button. Below the advertisement is a search bar labeled "Search IMS". At the bottom of the browser window, a PDF file named "anova applicationpdf" is open, and a "Show all" button is visible.

Acknowledgements

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Thank you!

