# Explorando a Integração de Realidade Estendida e Aprendizado de Máquina na Neuroreabilitação

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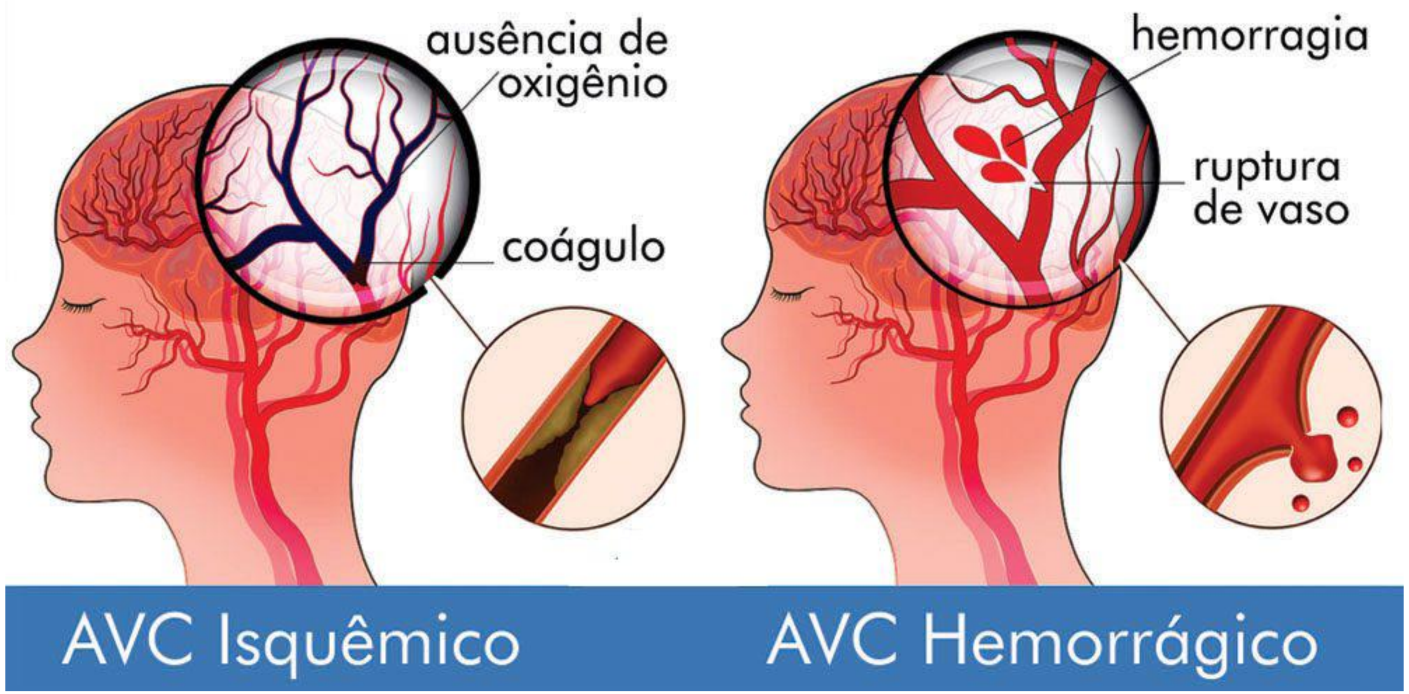
# Introdução

- O Acidente Vascular Cerebral é uma doença neurológica causada pela interrupção do suprimento de sangue que é enviado ao cérebro, geralmente ocorre devido ao rompimento de um vaso sanguíneo ou bloqueio por um coágulo.



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# Introdução

**No mundo**

- No mundo, 13.7 milhões de pessoas sofrem AVC por ano;
- 5.5 milhões vão a óbito;
- 5 milhões ficam com algum tipo de deficiência;
- Ocorre em 10% de pacientes com idade menor que 55 anos.

World Stroke Organization

**No Brasil**

- Foram mais de 188 mil internações causadas pelo AVC;
- Mais de 40 mil óbitos registrados;
- É uma das doenças que mais incapacitas os brasileiros.

MINISTÉRIO DA SAÚDE

# Introdução

Há diversos tipos de sequelas causadas pelo AVC, mas as motoras estão entre as mais comuns (Hemiplegia e Hemiparesia). O paciente perde a força muscular do braço e/ou da perna oposta à lesão cerebral. Dificuldades para andar, levantar ou realizar atividades utilizando os membros superiores, como pegar objetos, são alguns dos sintomas.

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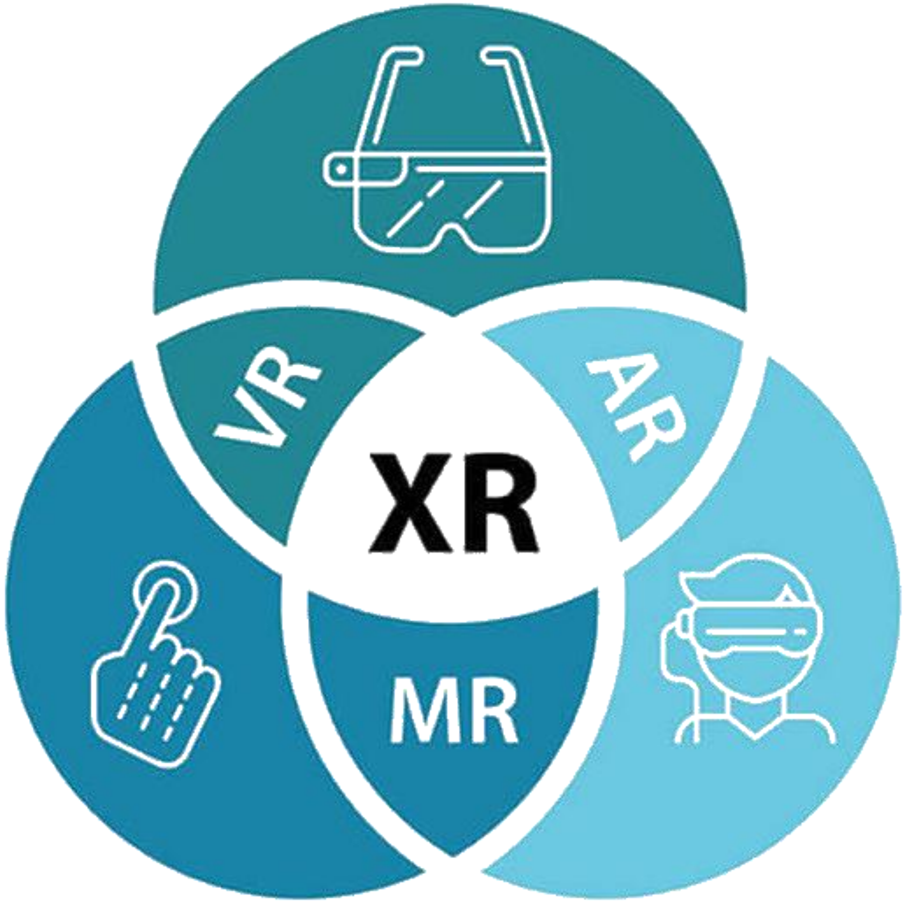
# Introdução

- 70% dos pacientes não conseguem retornar ao trabalho
- 50% tornam-se incapacitadas de executar das atividades do dia a dia
- As sessões de fisioterapia e terapia ocupacional são importantes para o processo de reabilitação dos pacientes

# Realidade Estendida

- Realidade Virtual
  - Interface avançada entre homem e máquina:
    - **Imersão**
    - **Interação**
    - Envolvimento
  - Ambiente tridimensional
- Realidade Aumentada
  - Combinação de objetos reais e virtuais, com predominância de objetos reais



# MiniCAVE Caverna Digital

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# AixCAVE – RWTH Aachen University

# Soluções voltadas à reabilitação

- Rastreamento Corporal
  - Óptico
  - Inercial
- Ambiente Imersivo
  - eStreet
  - GestureMaps
- **Armazenamento e tratamento dos dados**
  - **ReBase**

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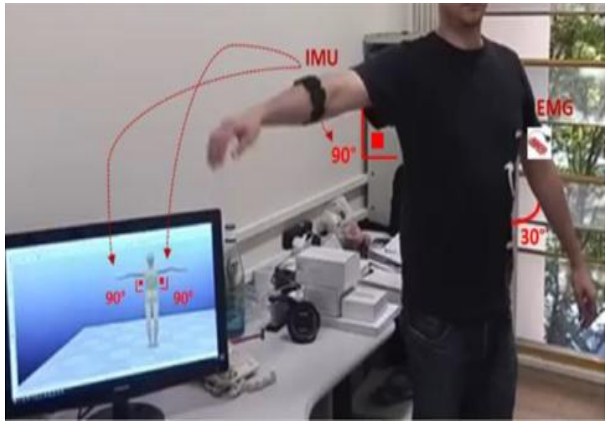
# VR for Motor and Cognitive Stimulus

GestureChair

GesturePuzzle

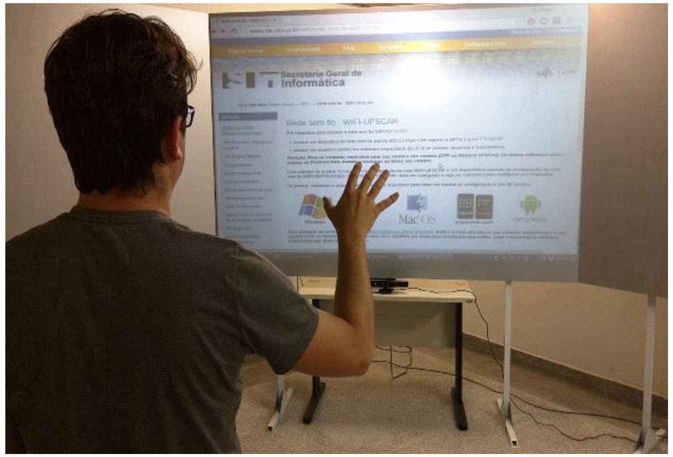
Mirror Therapy




e-House / e-Street

GestureChess

GestureChess




GestureMaps

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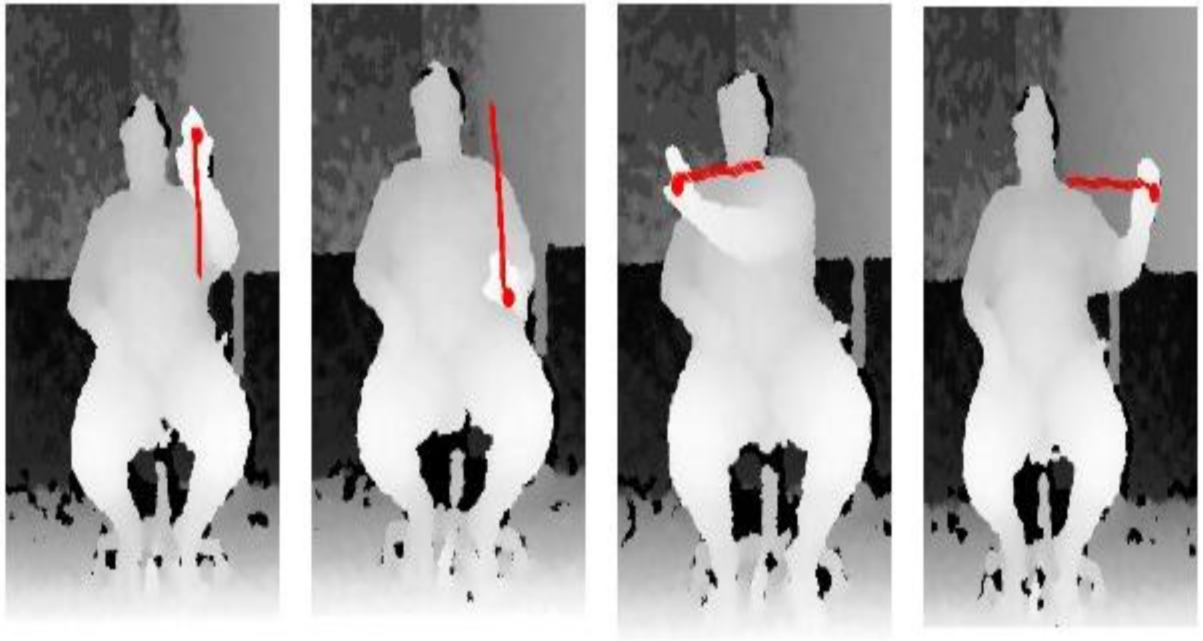
# GestureChair



Brandão AF; et al**.** Prevenção de atrofia muscular da articulação glenoumeral por meio de atividade física adaptada  a realidade virtual e reconhecimento de gestos. In: XVI SIMPÓSIO SESC DE ATIVIDADES FÍSICAS ADAPTADAS, 2013.

# GestureChess

Brandão AF; et al. GestureCollection for motor and cognitive stimuli: Virtual Reality and e-Health prospects. Journal of Health Informatics, V.10, n.1, pg 9-16, 2018.

# GesturePuzzle


Brandão AF; et al. GestureCollection for motor and cognitive stimuli: Virtual Reality and e-Health prospects. Journal of Health Informatics, V.10, n.1, pg 9-16, 2018.

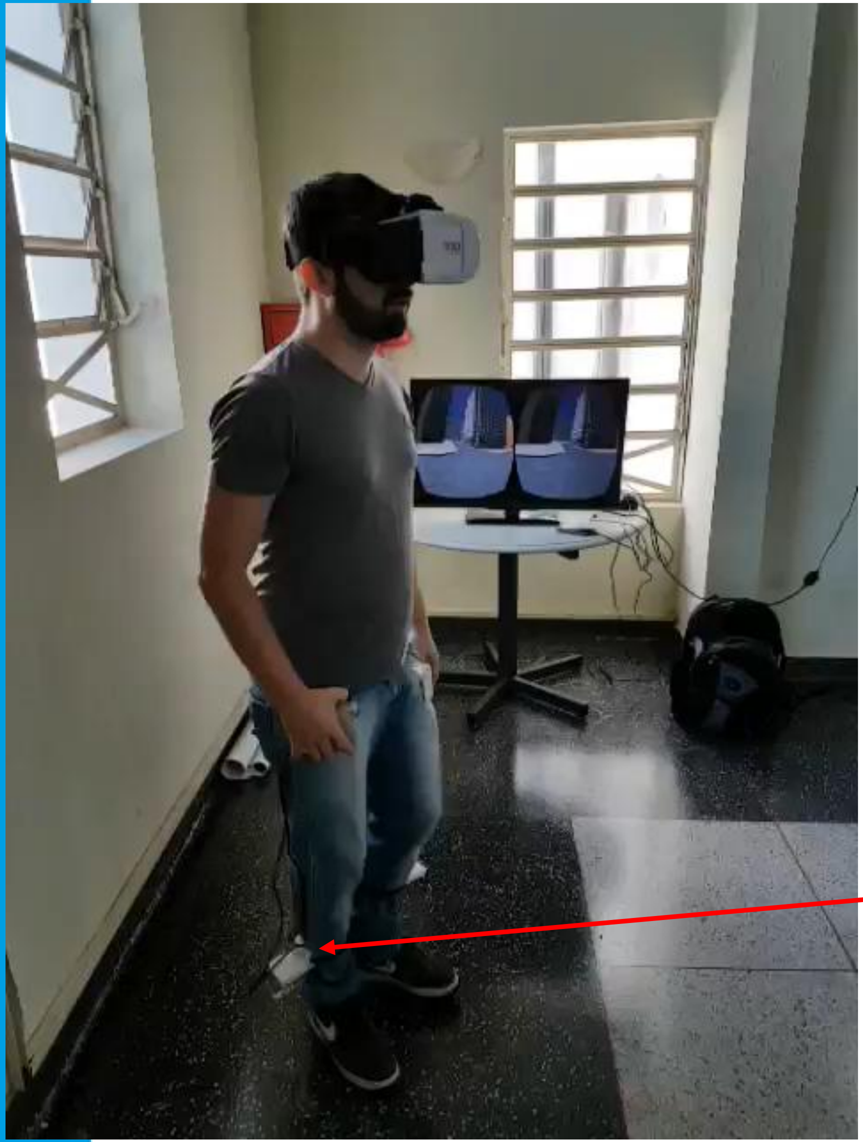
# GestureMaps (StreetView)

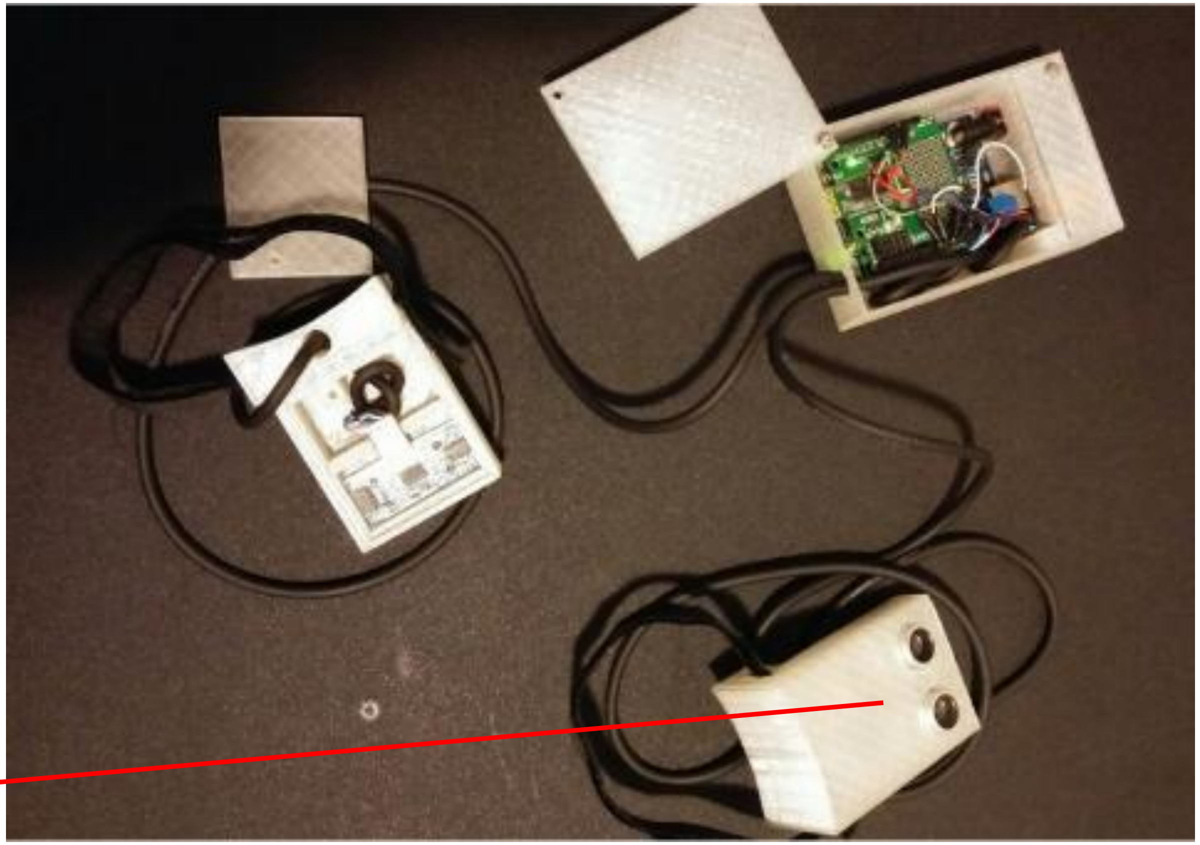

Brandão AF; et al. GestureCollection for motor and cognitive stimuli: Virtual Reality and e-Health prospects. Journal of Health Informatics, V.10, n.1, pg 9-16, 2018.

# Rastreamento Corporal

Óptico e Inercial

# Gesture Recognition from Ultrasound Sensor

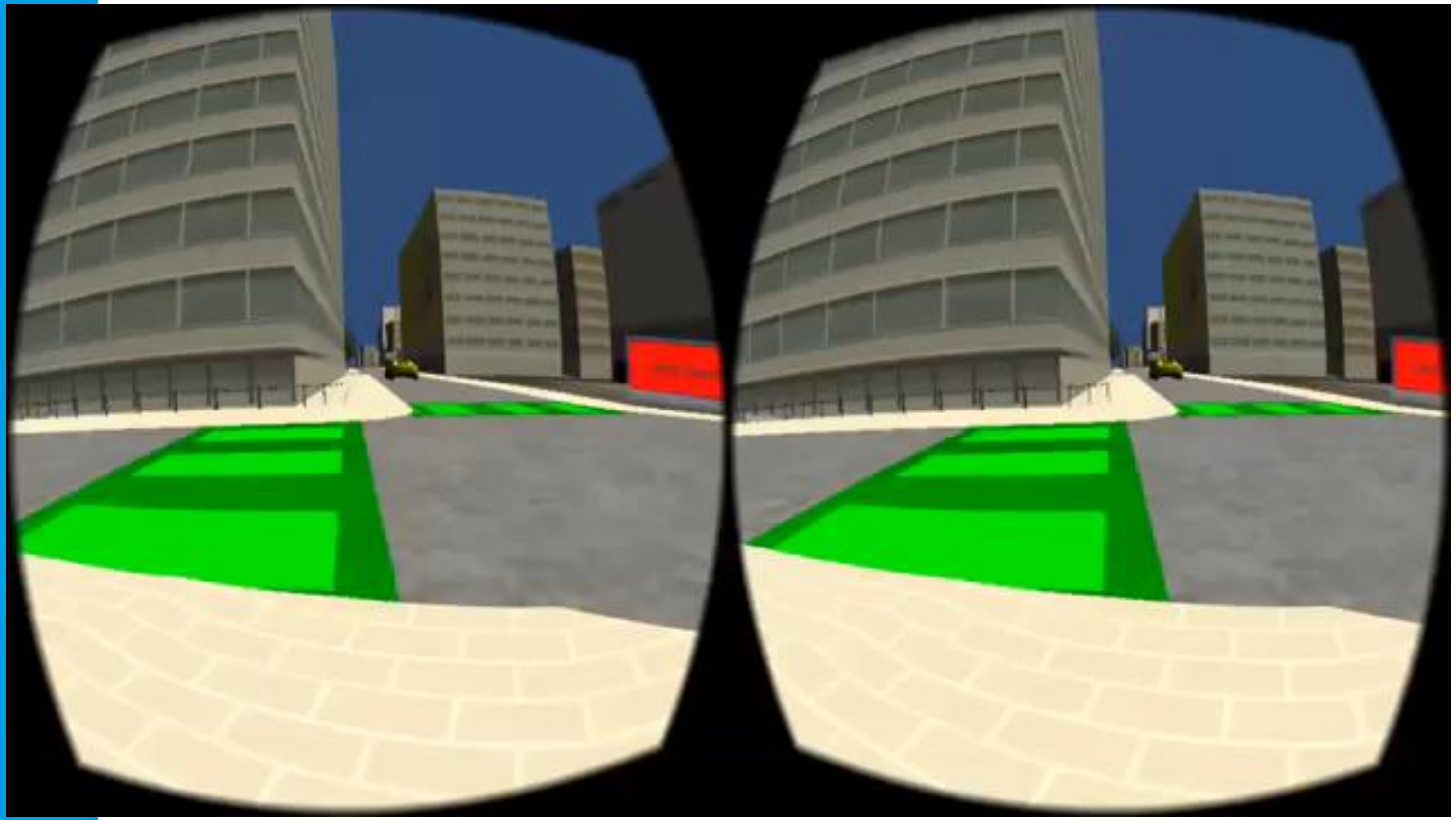




Brandão, AF et al. E-Street for Prevention of Falls of the Elderly an Urban Virtual Environment for Human–Computer Interaction from Lower Limb Movements. In: Brazilian Technology Symposium. UNICAMP, Campinas, 2017. (Ahead of print Springer).

# Technological Innovation: e-Street

## e-Street / e-House



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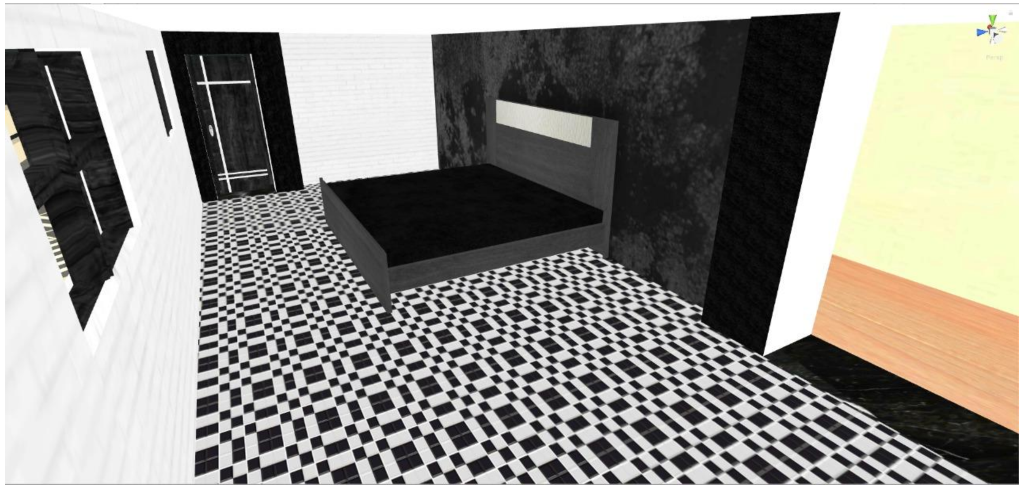
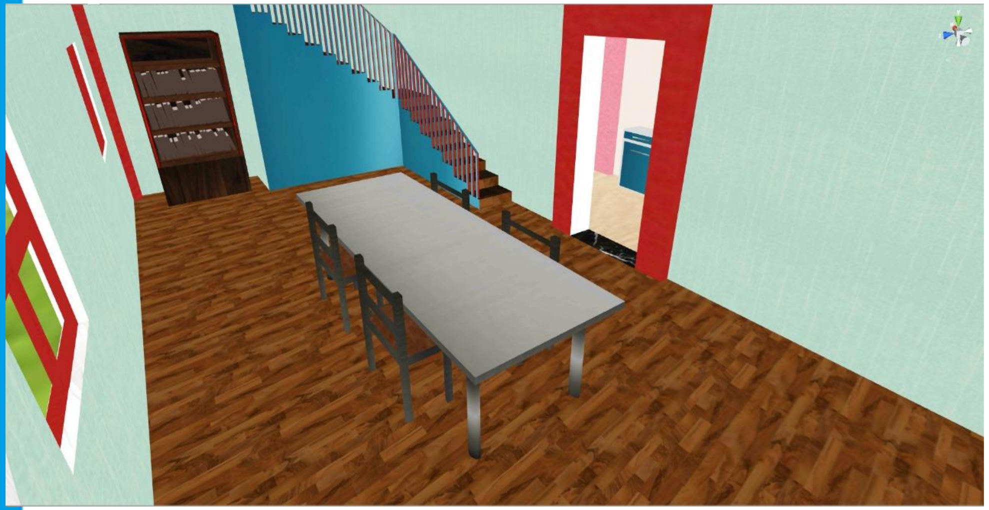
# Technological Innovation: e-Street





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# Biomechanics sensor nodes for body tracking: a development solution for virtual reality interaction

Elvis Hernandes Ribeiro[1], Marcelo P. Guimarães[2,3],
José R. F. Brega[3,4], Alexandre F. Brandão[3], Diego R. C. Dias

[1]Federal University of São João del–Rei – UFSJ
[2]São Paulo State University – UNESP
[3]Federal University of São Paulo – UNIFESP/Postgraduate Program – UNIFACCAMP,
[4]Brazilian Institute of Neuroscience and Neurotechnology - BRAINN

October 19, 2021

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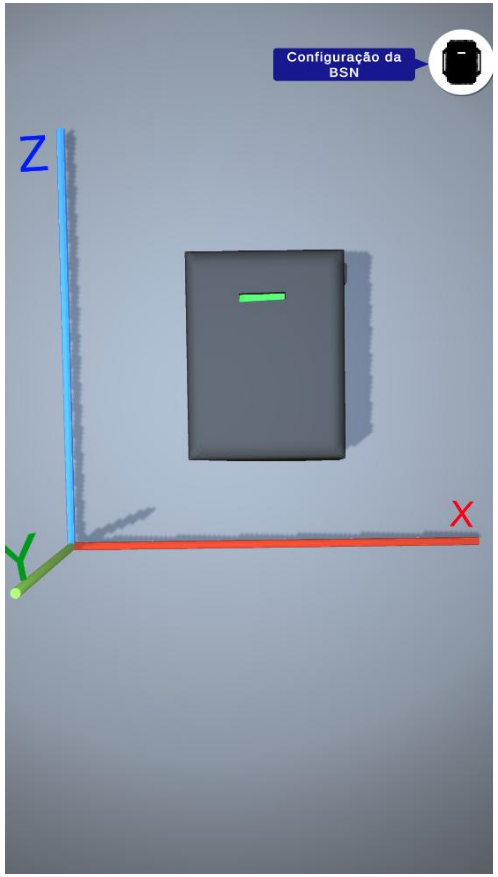
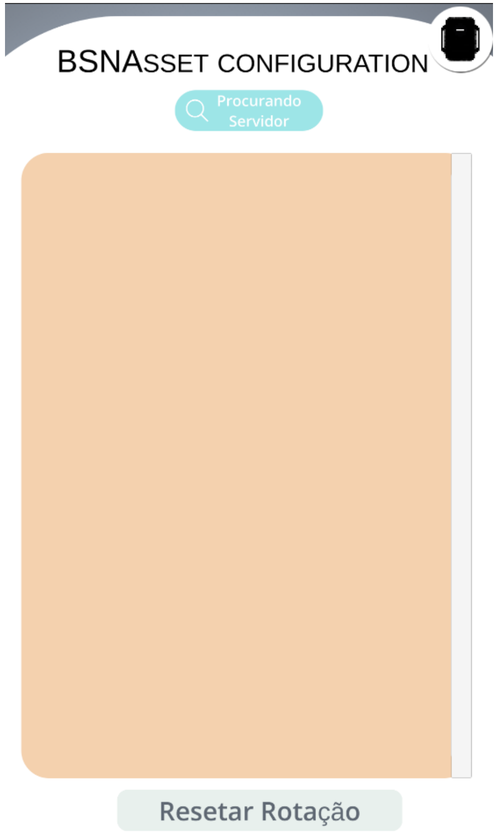
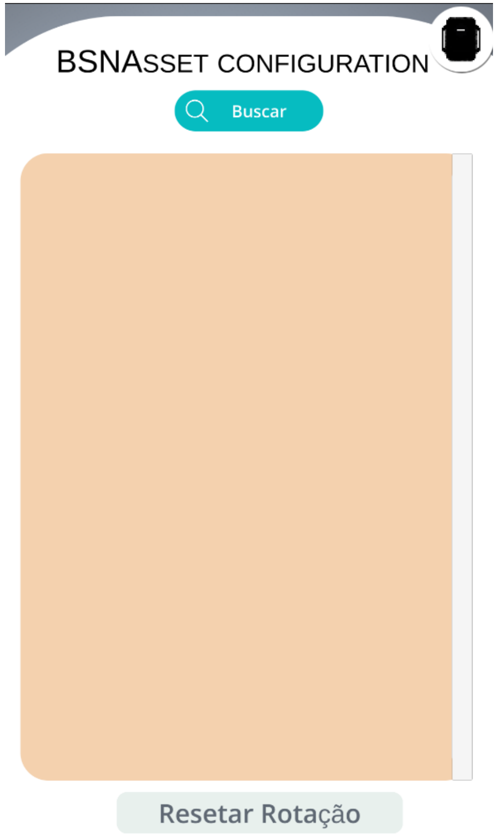
# Biomechanics Sensor Node - BSN

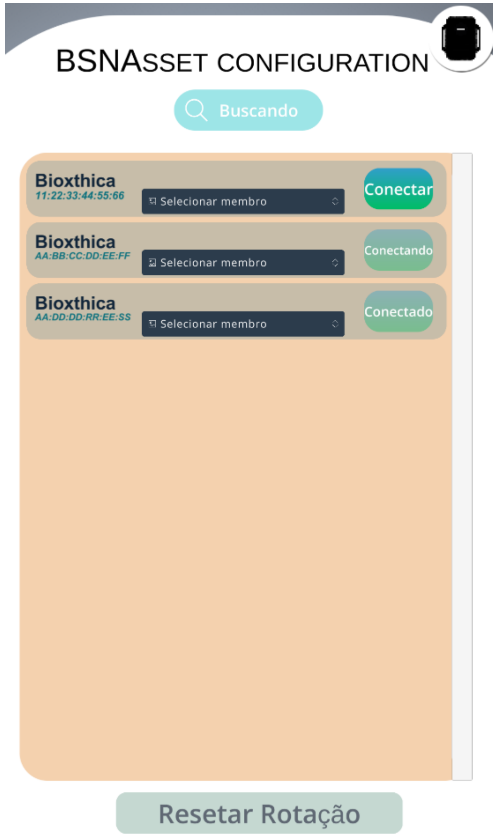
- Wearable devices
- IMU Sensor
- *Bluetooth Low Energy (BLE) Communication*
- Low cost
- Asset for Unity
- Portable to Android and iOS
- Easy to add in any Unity projects
- Connection of multiple devices simultaneously
- Friendly GUI
- Remote configuration

# Grafical User Interface - GUI



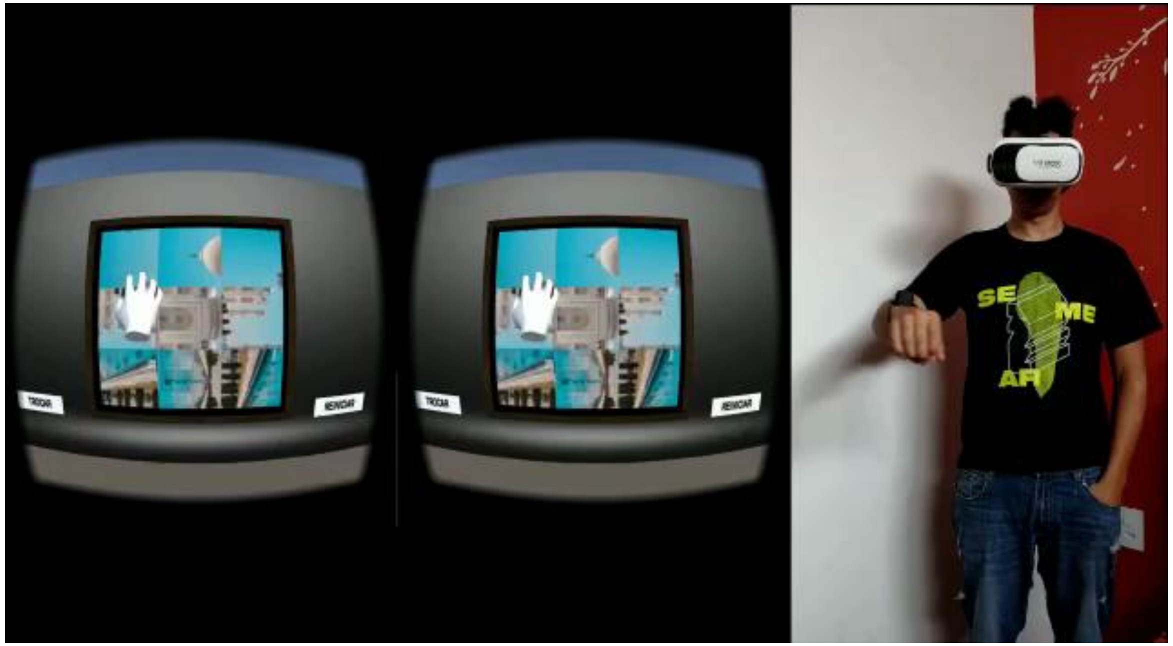



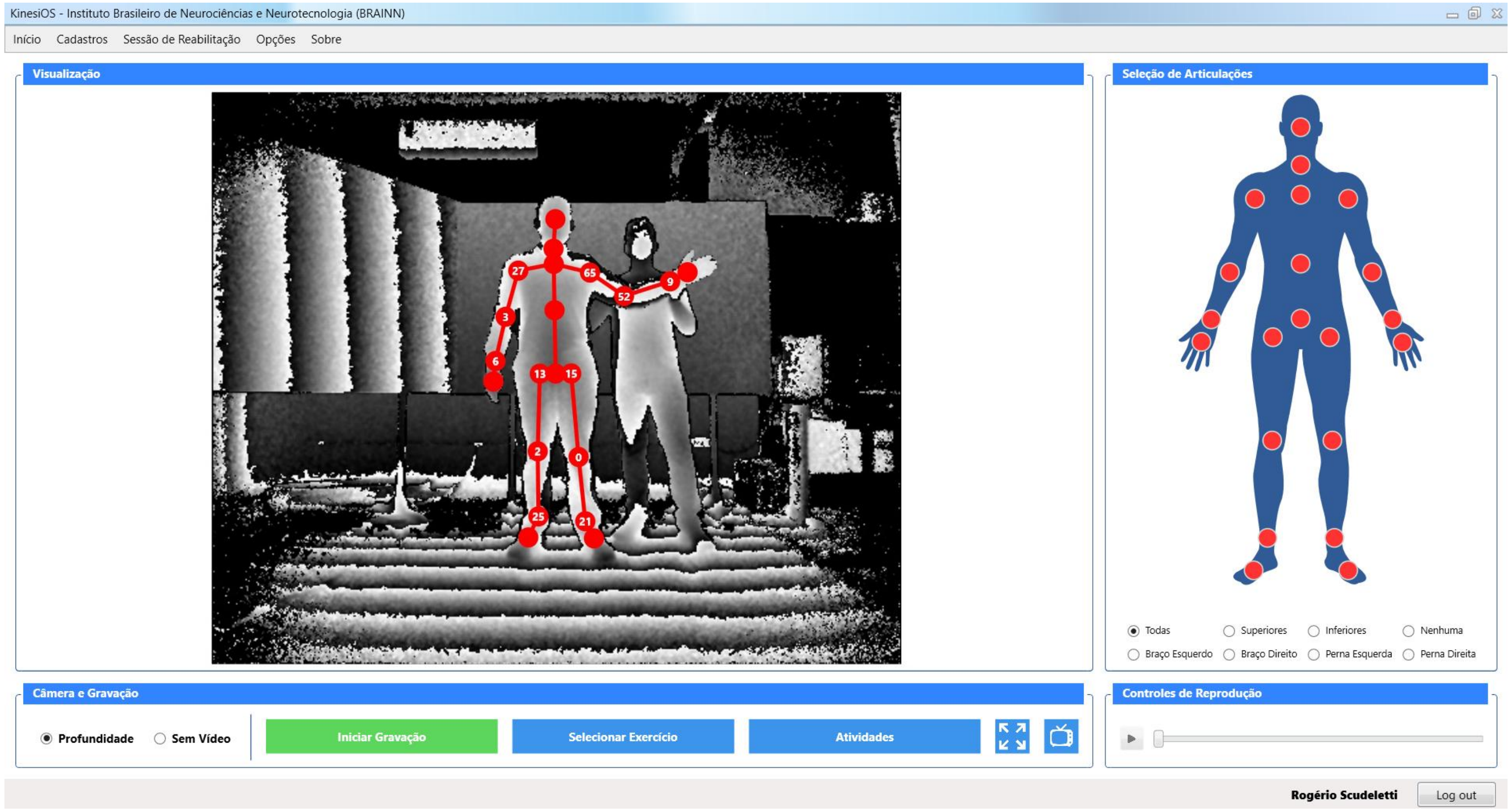
# Results

eStreet

Puzzle Brainn



# KinesiOS



KinesiOS - Instituto Brasileiro de Neurociências e Neurotecnologia (BRAINN)
Início
Cadastros
Sessão de Reabilitação
Opções
Sobre
Visualização
Seleção de Articulações
Todas
Superiores
Inferiores
Nenhuma
Braço Esquerdo
Braço Direito
Perna Esquerda
Perna Direita
Câmera e Gravação
Profundidade
Sem Vídeo
Iniciar Gravação
Selecionar Exercício
Atividades
Controles de Reprodução
Rogério Scudeletti
Log out

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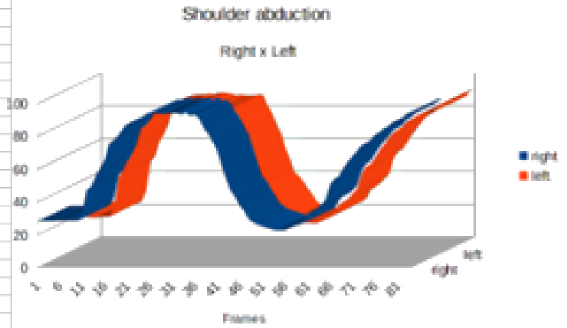
# Objetivo primário

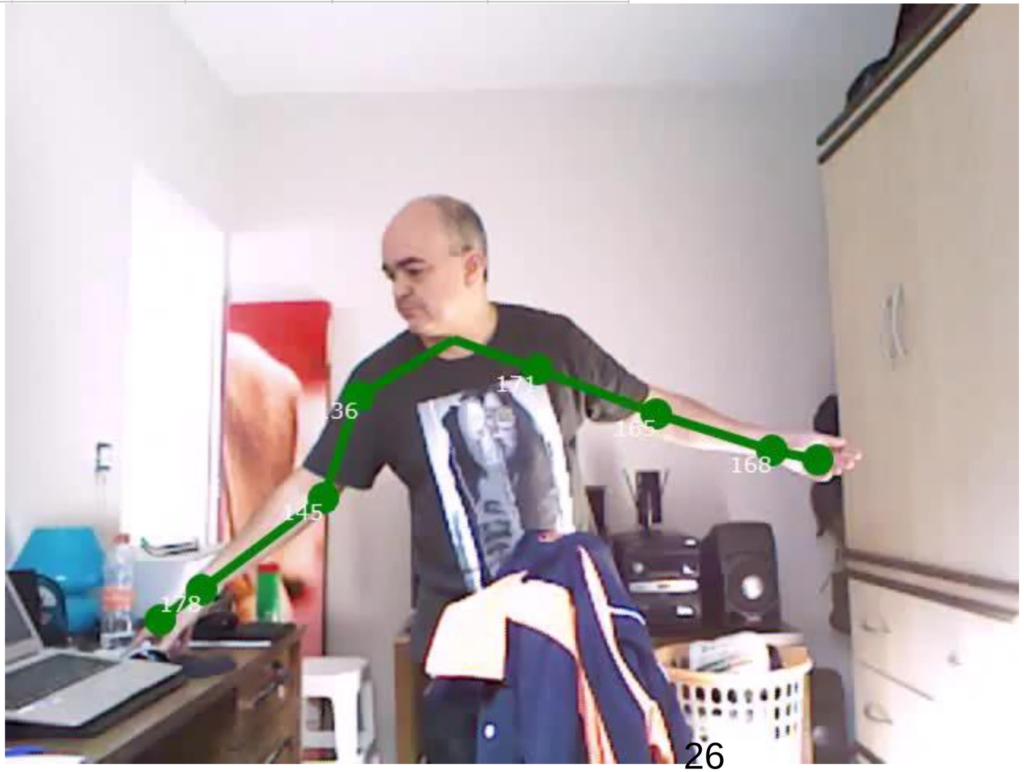
- Obter informações sobre os movimentos realizados pelos usuários nas sessões de tratamento, proporcionando dados mais precisos sobre os estágios de evolução dos pacientes
- Monotonia e repetição das sessões de fisioterapia e terapia funcional, o que faz com que alguns pacientes desistam da realização do tratamento, por falta de motivação

# KINESIOrom – range of motion measurement


| Frame | ShoulderAngleRight | ElbowAngleRight | ShoulderAngleLeft | ElbowAngleLeft |
|---|---|---|---|---|
| 1 | 50.06 | 176.44 | 52.88 | 169.34 |
| 2 | 53.16 | 177.19 | 54.77 | 169.62 |
| 3 | 53.8 | 177.5 | 55.87 | 169.02 |
| 4 | 56.31 | 179.85 | 59.32 | 170.73 |
| 5 | 59.34 | 179.9 | 62.41 | 170.7 |
| 6 | 63.99 | 179.97 | 63.78 | 170.25 |
| 7 | 67.31 | 179.39 | 65.82 | 171.36 |
| 8 | 67.87 | 179.93 | 66.71 | 171.03 |
| 9 | 68.29 | 179.7 | 67.65 | 171.24 |
| 10 | 75.77 | 179.81 | 68.84 | 173.08 |
| 11 | 75.02 | 179.56 | 76.9 | 171.36 |
| 12 | 75.58 | 178.24 | 80.67 | 171.56 |
| 13 | 75.58 | 178.24 | 80.67 | 171.56 |
| 14 | 79.34 | 178.5 | 82.83 | 175.54 |
| 15 | 78.63 | 172.38 | 86.09 | 177.28 |
| 16 | 80.31 | 172.62 | 87.29 | 179.18 |
| 17 | 82.51 | 172.26 | 89.69 | 178.55 |
| 18 | 85.12 | 173.81 | 91.39 | 177.73 |
| 19 | 86.68 | 174.51 | 92.26 | 177.78 |





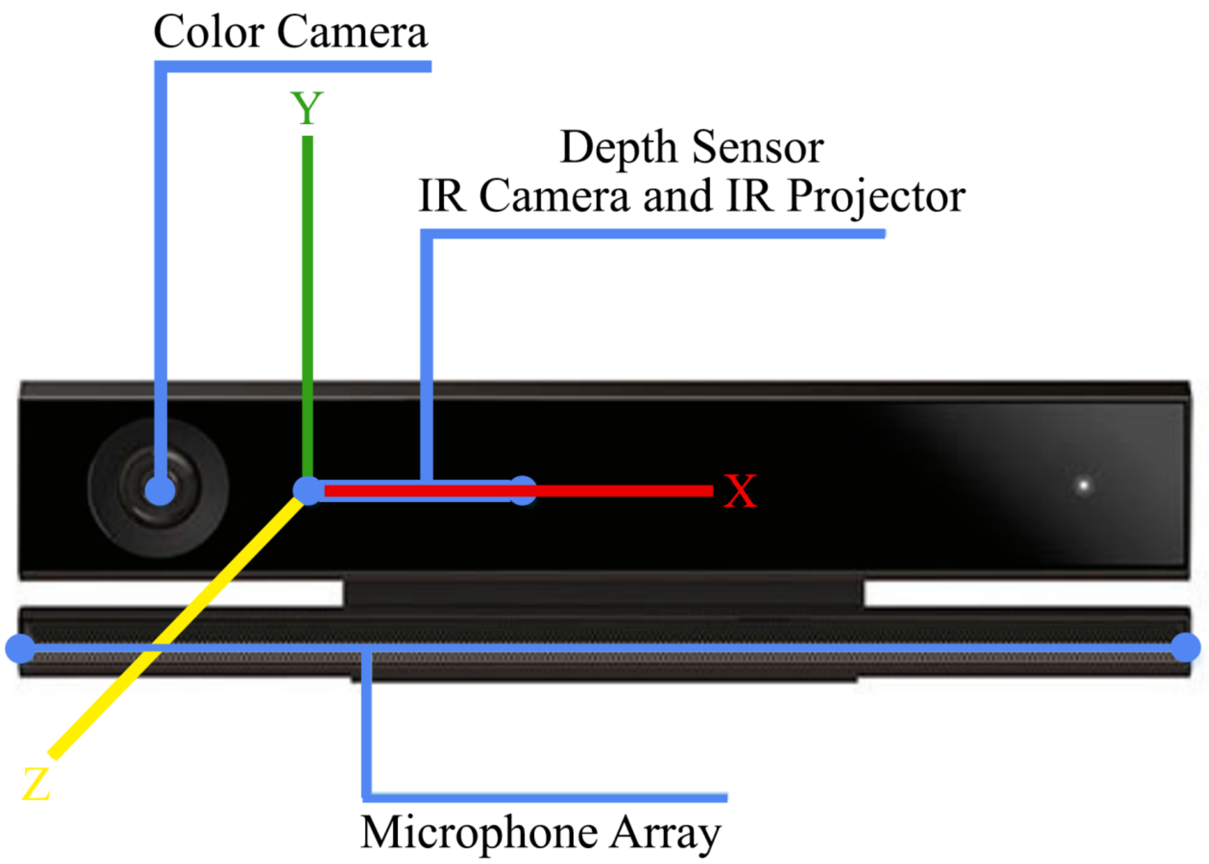





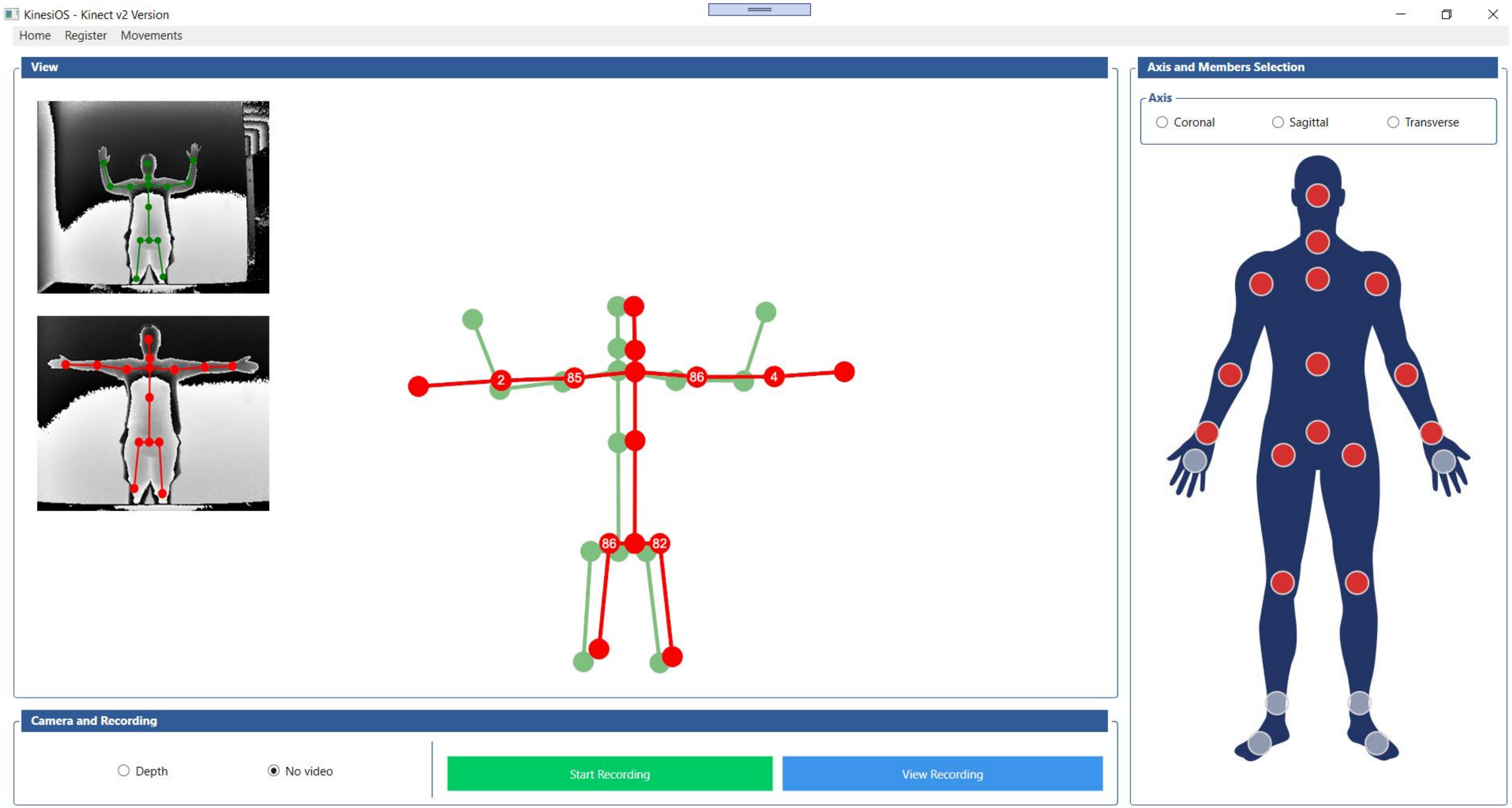

Brandão AF; et al. RehabGesture: an alternative tool for measuring human movement. Telemedicine and e-Health, v.22, n.7, p. 1-6, 2016.

# MATERIAL AND METHODS

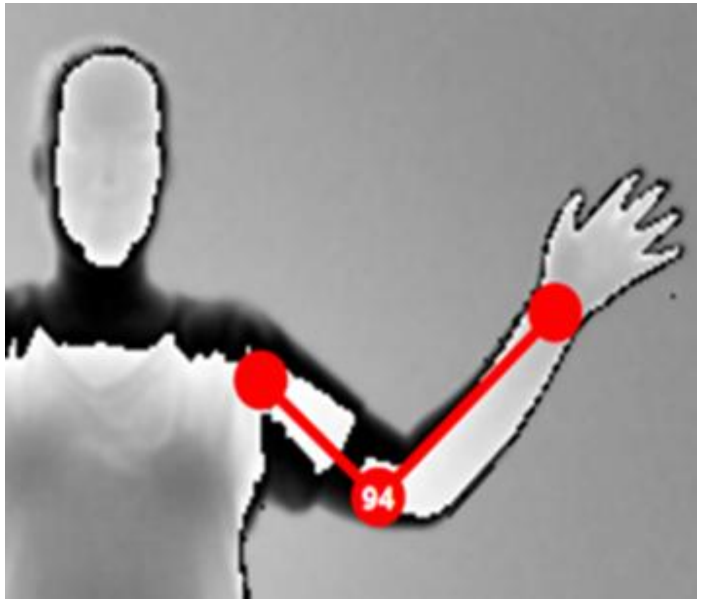
## Microsoft Kinect One

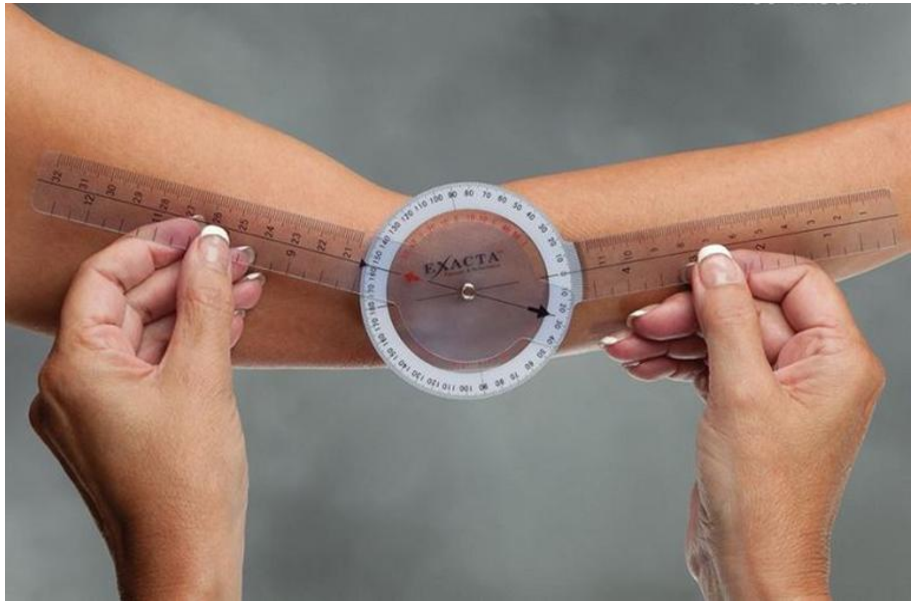


# MATERIAL AND METHODS

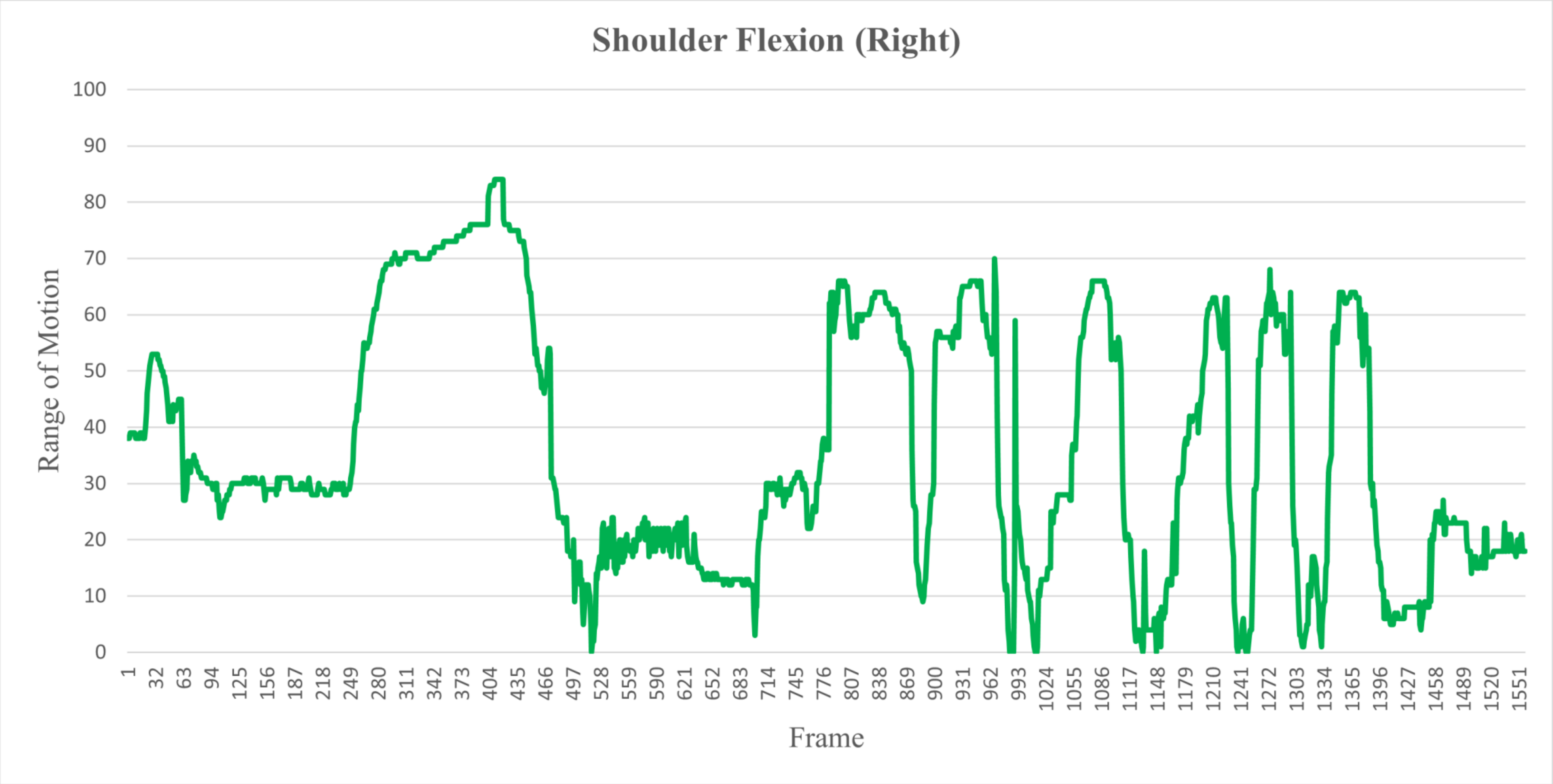


# O que é amplitude de movimento?

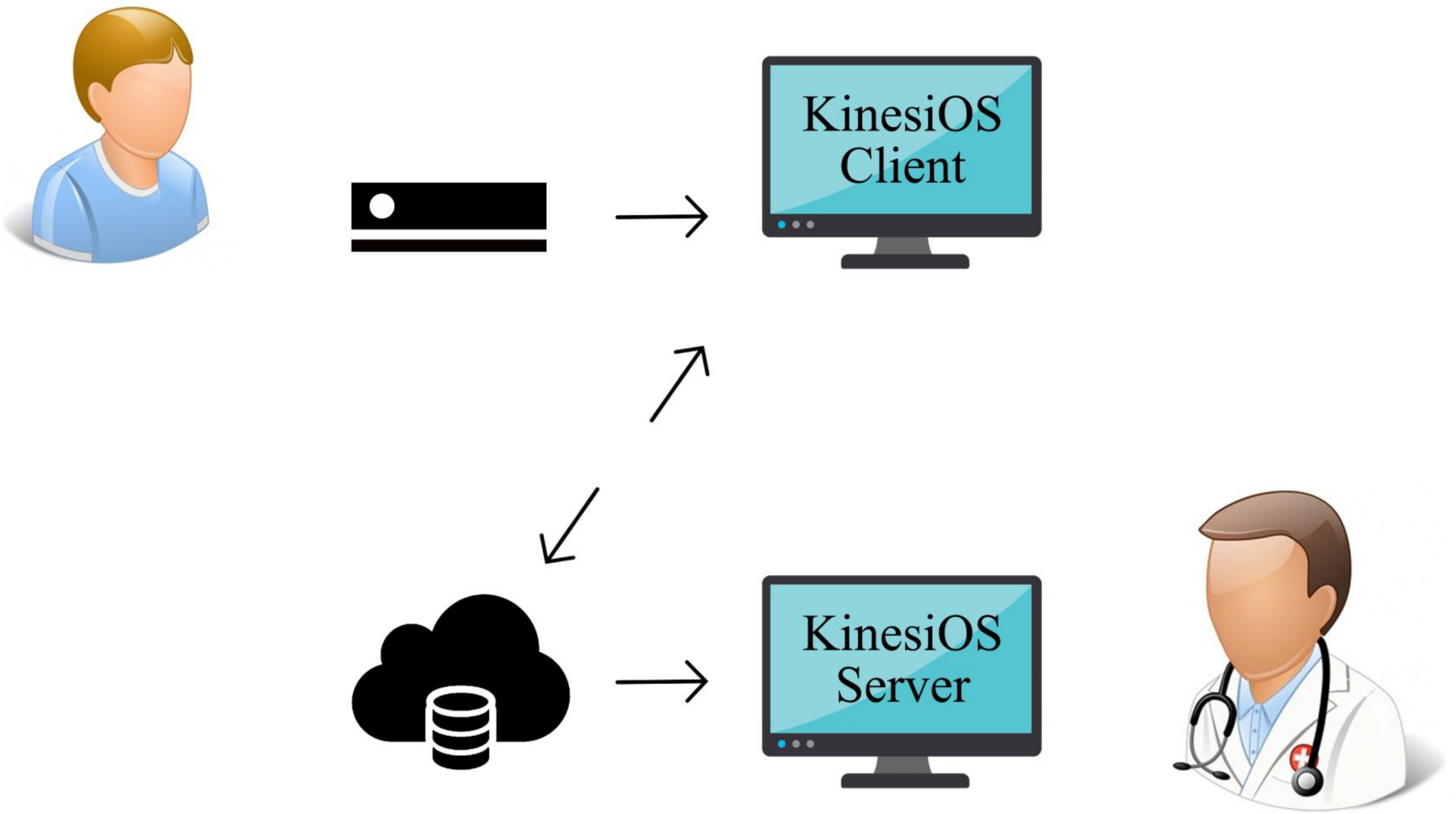


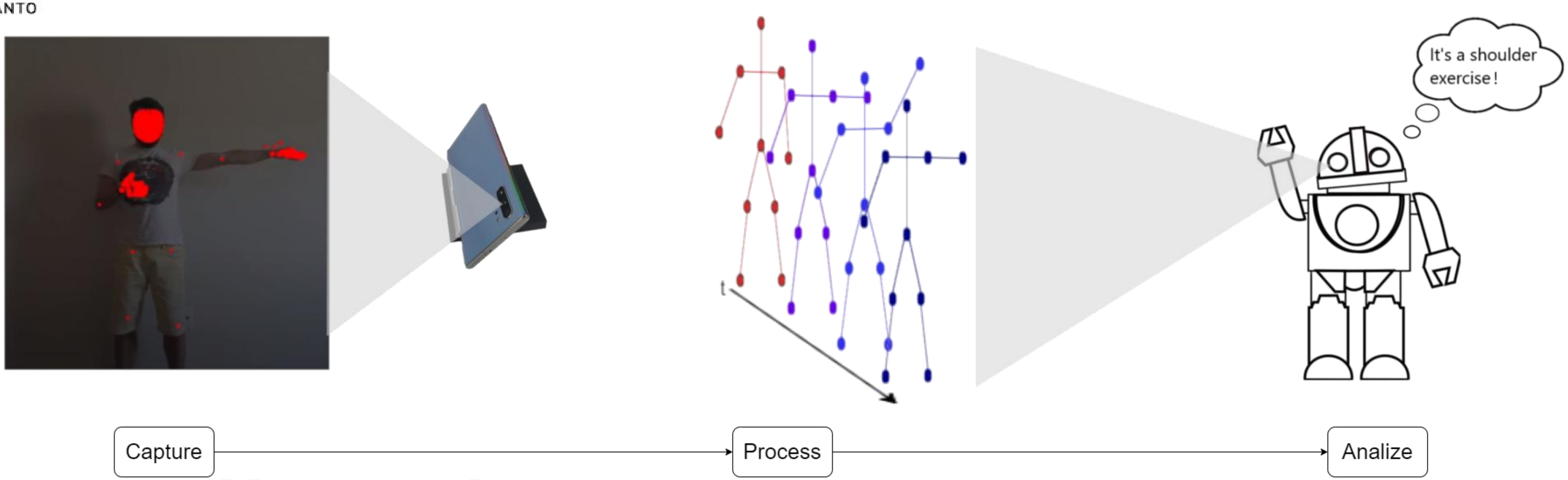



# RESULTS AND FUTURE WORK



# TELEREHABILITATION






# Media Pipe

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# Classification of Human Movements with Motion Capture Data in a Motor Rehabilitation Context

Luis Rodrigues[1], Diego Dias[2], Marcelo Guimarães[3], Alexandre Brandão[4], Leonardo Rocha[2], Rogério Iope[1], José Brega[1].

1 unesp UNIVERSIDADE ESTADUAL PAULISTA "JÚLIO DE MESQUITA FILHO"
2 UFSJ Universidade Federal de São João del-Rei
3 UNIFESP UNIVERSIDADE FEDERAL DE SÃO PAULO 1933
4 UNICAMP BRAINN BRAZILIAN INSTITUTE OF NEUROSCIENCE AND NEUROTECHNOLOGY

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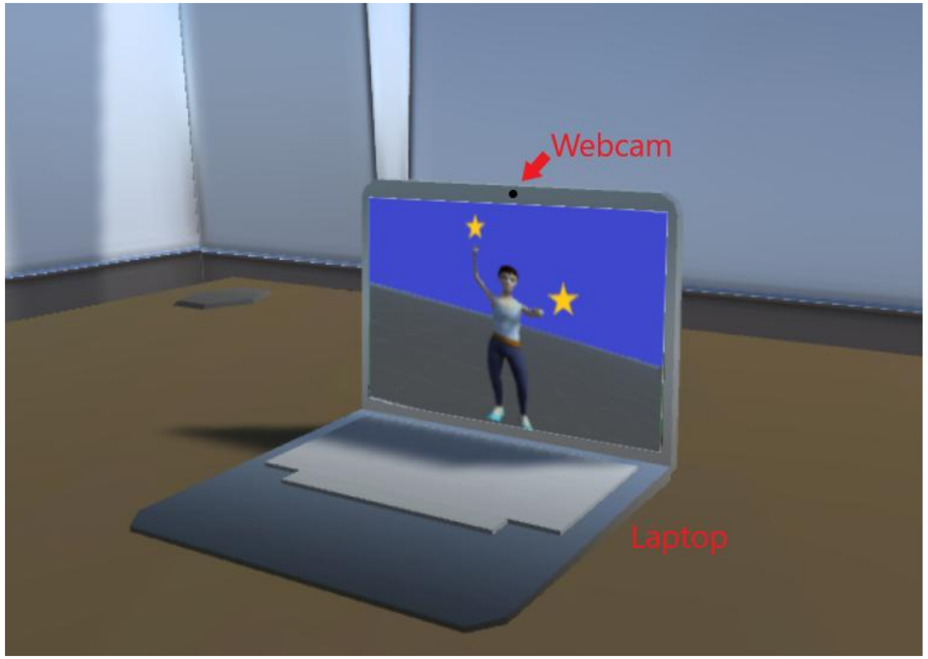
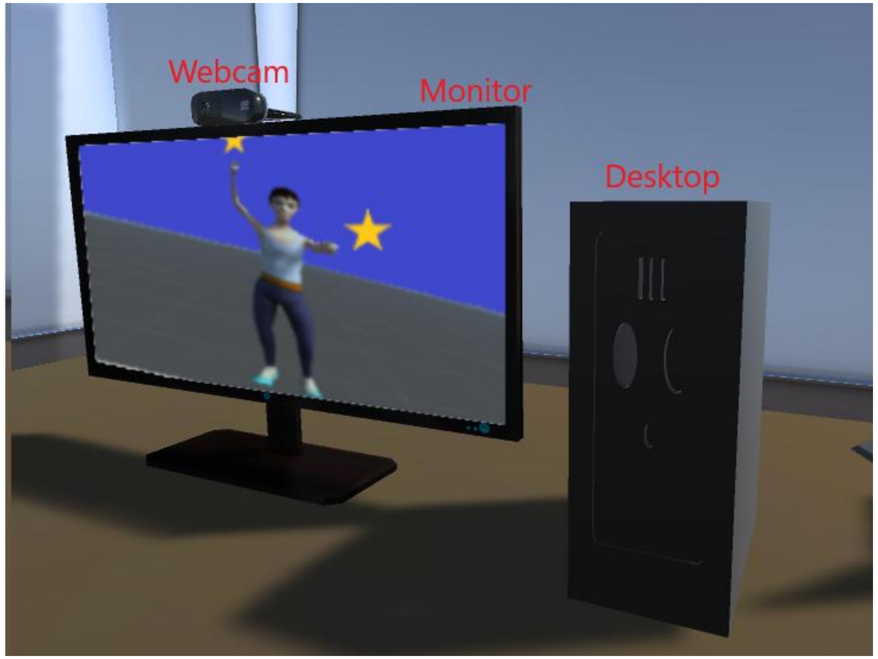
# Required Equipaments

Smartphones nowadays have enough processing power and new algorithms are being created.

# Required Equipaments

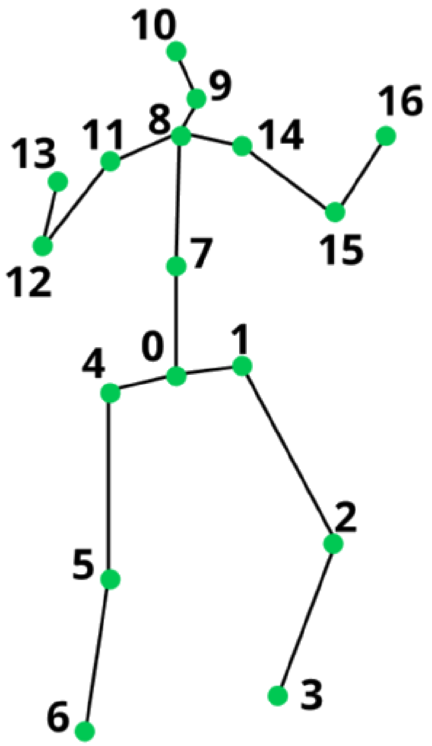
Computers with no specific GPUs can also be used for tracking



# Obtaining Motion Capture Data

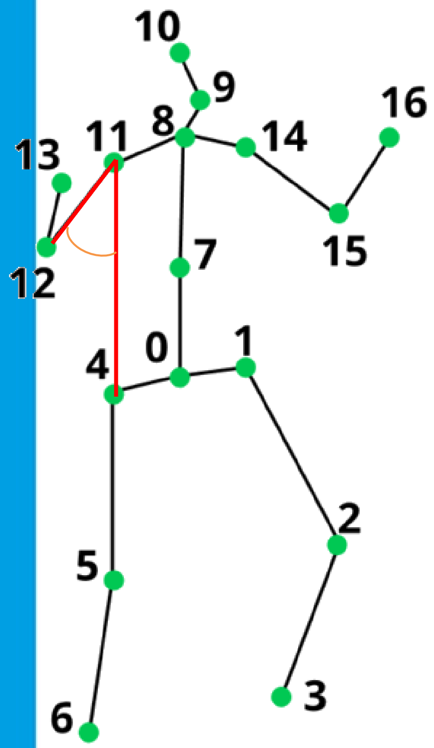
The positions of the body joints are the result of the pose estimation and tracking algorithm




0. Bottom Torso
1. Left Hip
2. Left Knee
3. Left Foot
4. Right Hip
5. Right Knee
6. Right Foot
7. Center Torso
8. Upper Torso
9. Neck Base
10. Center Head
11. Right Shoulder
12. Right Elbow
13. Right Hand
14. Left Shoulder
15. Left Elbow
16. Left Hand

# Machine Learning Input

Feature Extraction Step: Joints related to right arm is selected and converted into angles.




0. Bottom Torso
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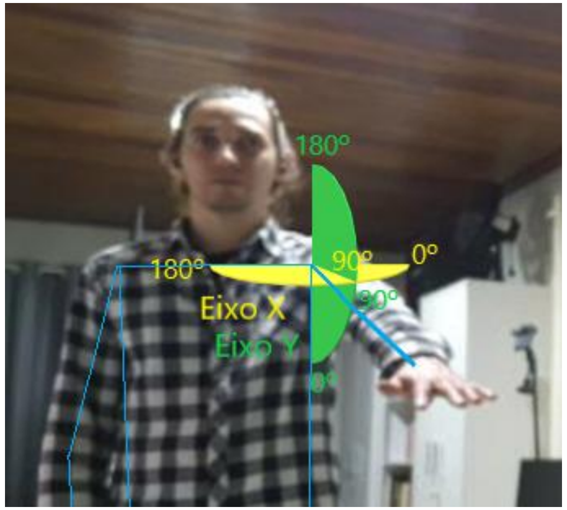
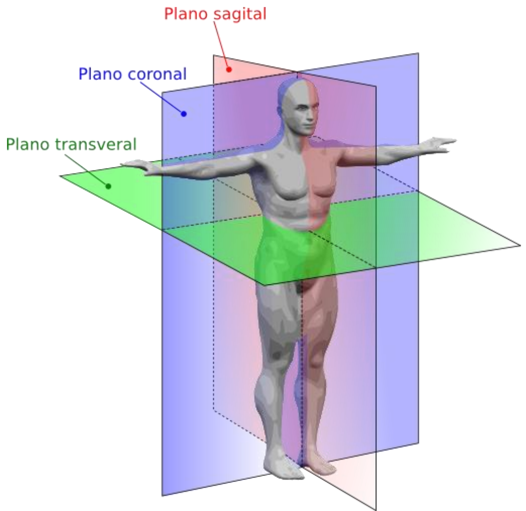
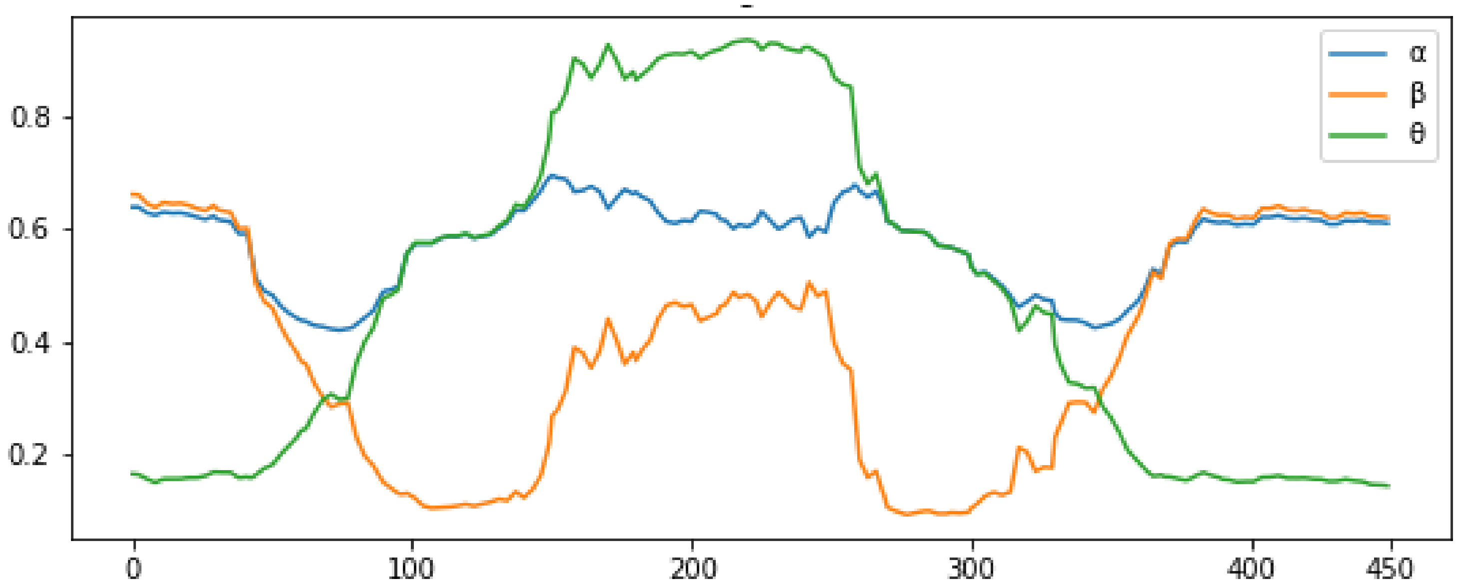
13. Right Hand
14. Left Shoulder
15. Left Elbow
16. Left Hand

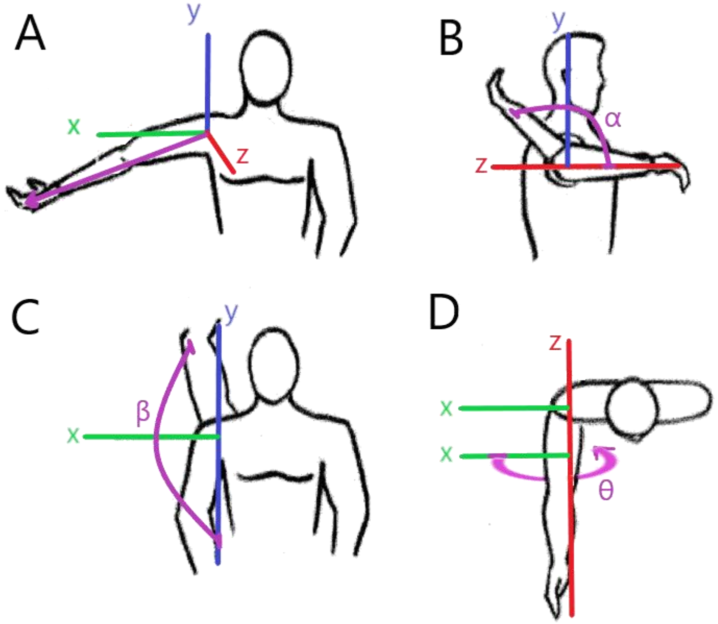


# Machine Learning Preprocessing

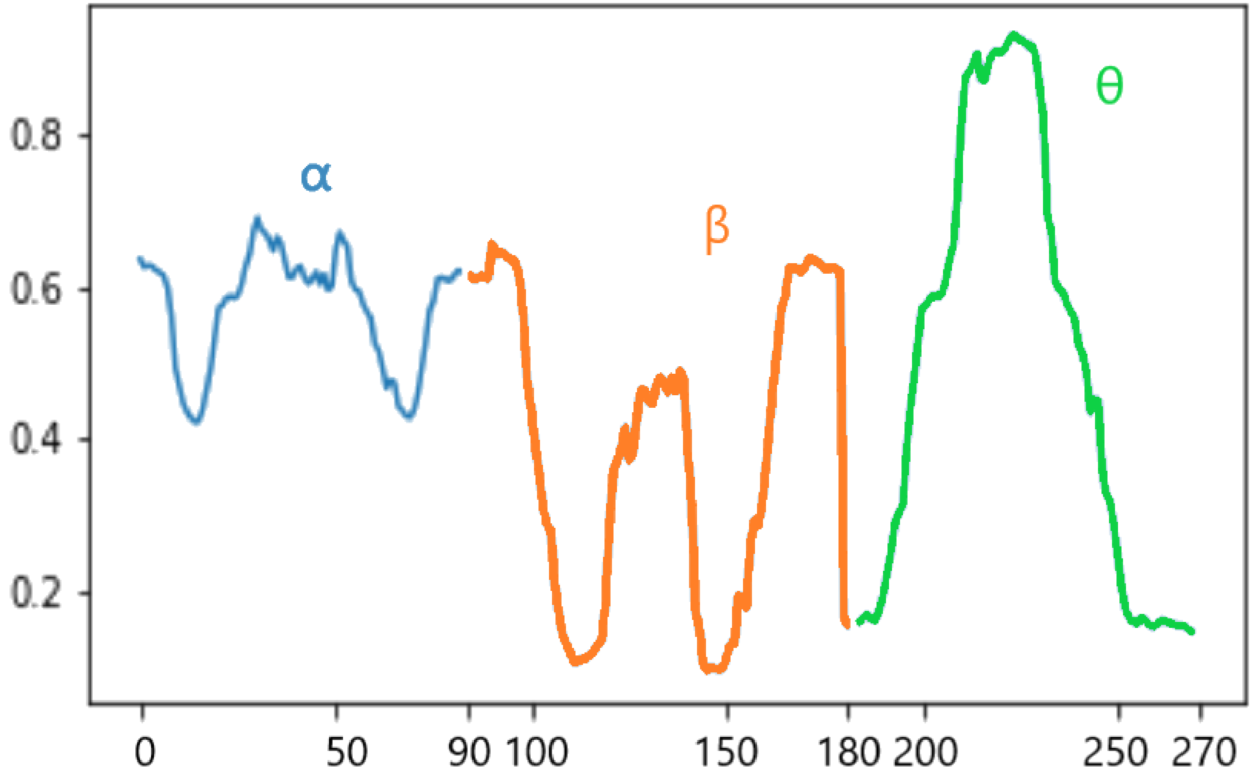
Data Preprocessing: the different types of angles will be concatenated to form a single input array.



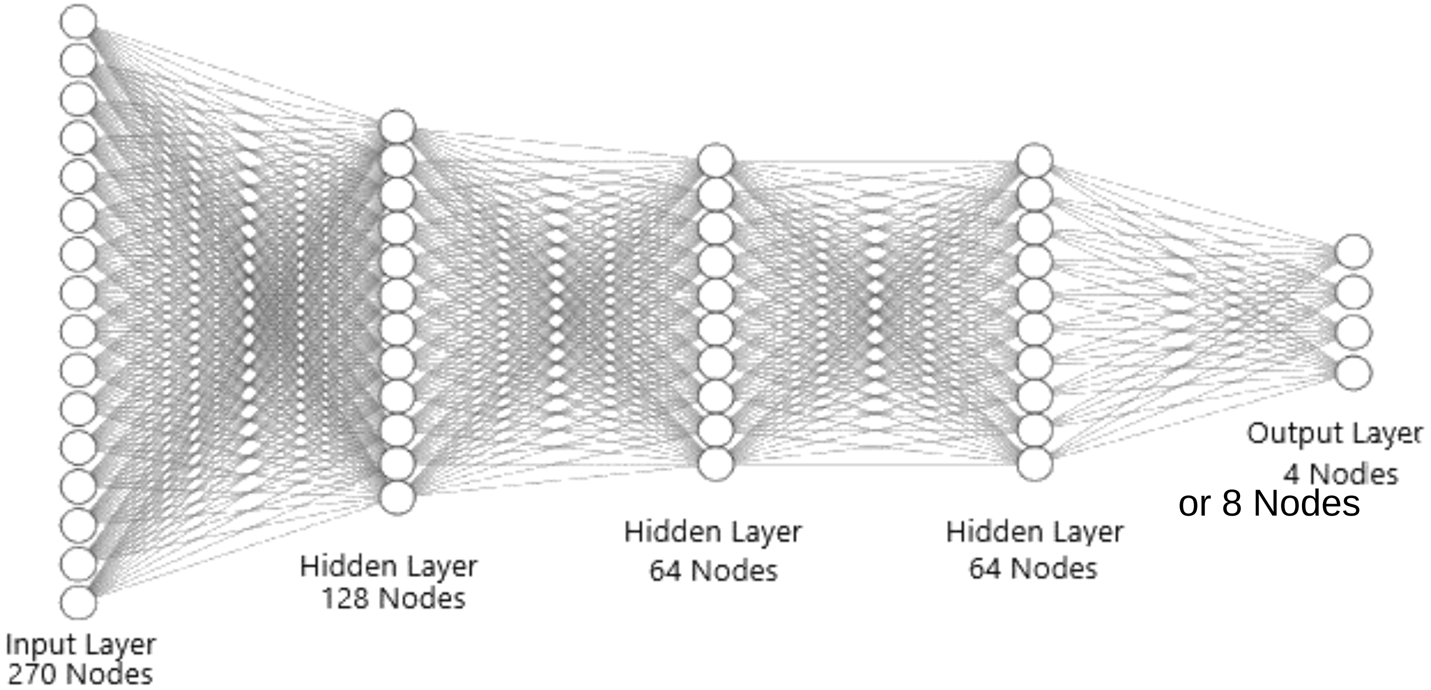
# Machine Learning Preprocessing

Final Result of Data Preprocessing: 90 frames of 3 types of angles result in an array of length 270



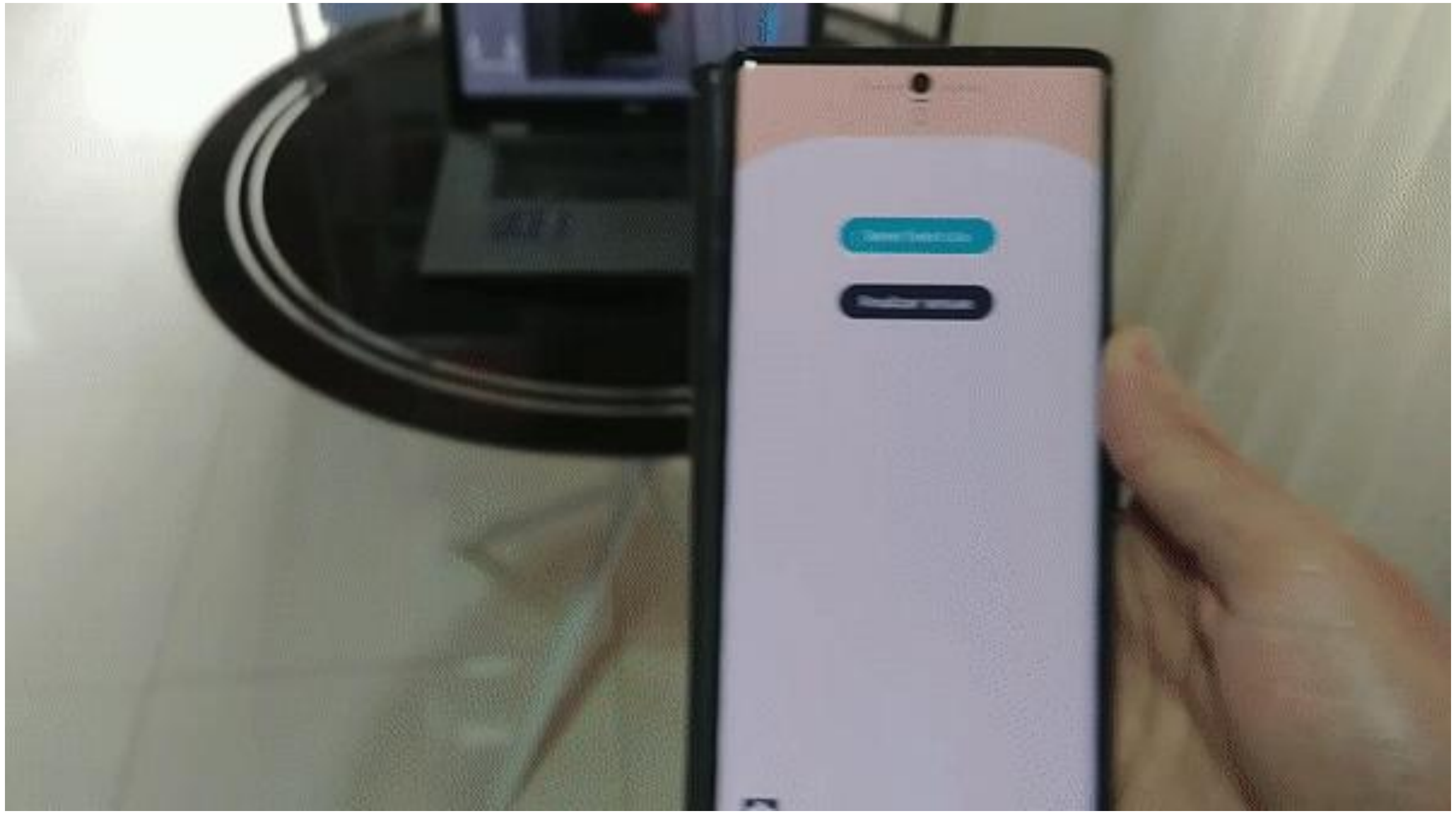
# Machine Learning Architecture

Selected Models: Custom ANN architecture for Classification



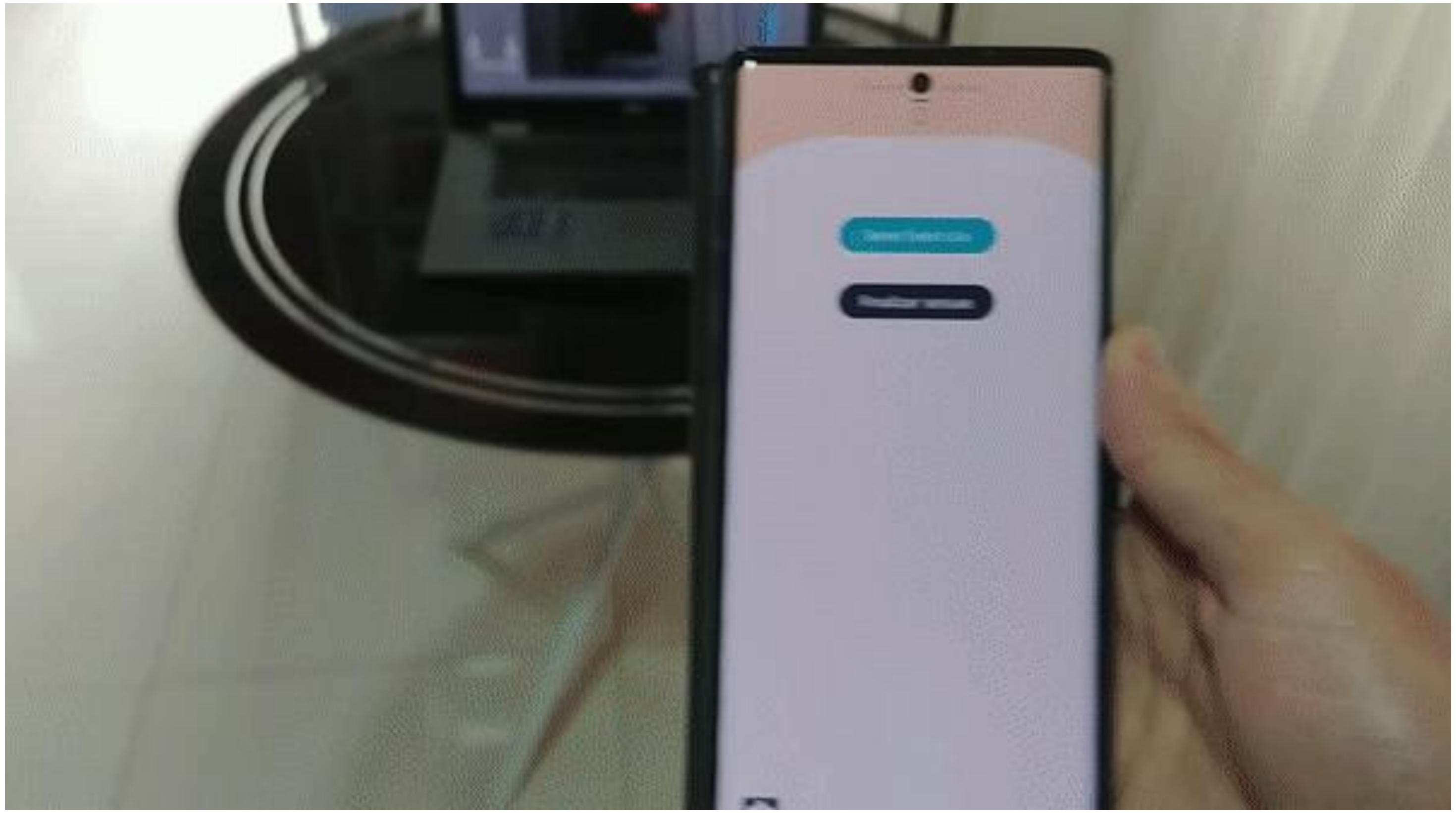
# Machine Learning Training

- Selected Approach: Supervised Classification of the Movements



# Machine Learning Training

- Model Input (X): The articulation over time.
- Model Output (Y): Probability of belonging to each of 8 classes/movements



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# Machine Learning Results

8 movements are predicted correctly in a validation set (not seen in the train step)

| | | Predicted Values | | | | | | | |
|---|---|---|---|---|---|---|---|---|---|
| | | Coronal90 | Coronal180 | Sagittal90 | Sagittal180 | Transversal90 | Transversal180 | Elbow90 | Elbow180 |
| Real Values | Coronal90 | 7 | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Coronal180 | 0 | 6 | 0 | 0 | 0 | 0 | 0 | 0 |
| | Sagittal90 | 0 | 0 | 5 | 0 | 0 | 0 | 0 | 0 |
| | Sagittal180 | 0 | 0 | 0 | 6 | 1 | 0 | 0 | 0 |
| | Transversal90 | 0 | 0 | 0 | 0 | 7 | 0 | 0 | 0 |
| | Transversal180 | 0 | 0 | 0 | 0 | 2 | 8 | 0 | 0 |
| | Elbow90 | 0 | 0 | 0 | 0 | 0 | 0 | 5 | 0 |
| | Elbow180 | 0 | 0 | 0 | 0 | 0 | 0 | 3 | 5 |

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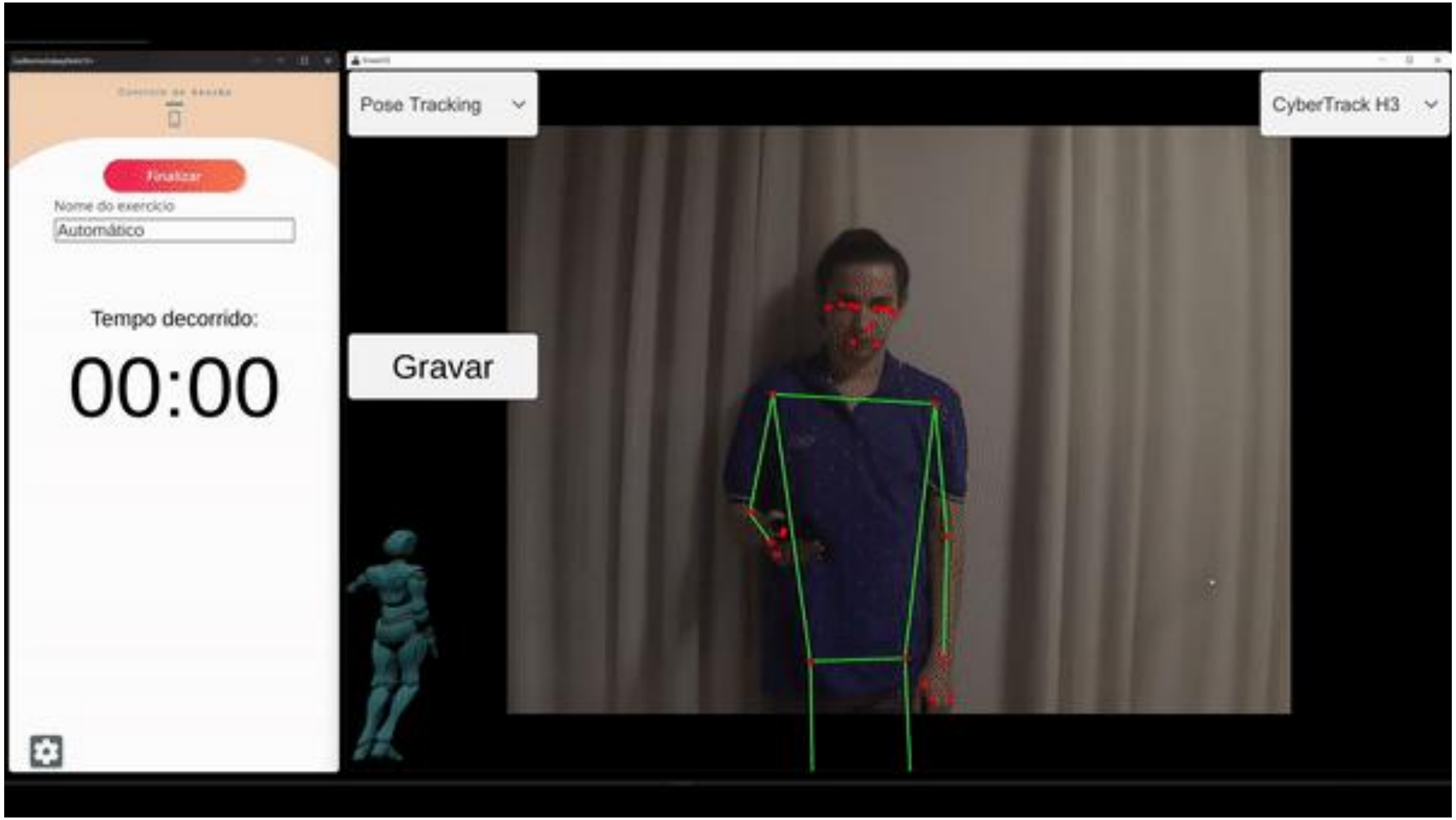


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SVR2021
23rd Symposium on Virtual and Augmented Reality

# Dados

Armazenamento e processamento dos dados provenientes das sessões de reabilitação neuromotora

# **ReBase**: data acquisition and management system for neuromotor rehabilitation supported by virtual and augmented reality

Tiago Trotta[1], Marcelo P. Guimarães[3,4], Alexandre F. Brandão[4], Leonardo C. D. da Rocha[1], Rogério L. Iope[2], José R. F. Brega[2], Diego R. C. Dias[1,4]

[1]Federal University of São João del–Rei – UFSJ, [2]São Paulo State University – UNESP, [3]Federal University of São Paulo – UNIFESP/Postgraduate Program – UNIFACCAMP, [4]Brazilian Institute of Neuroscience and Neurotechnology - BRAINN

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- These applications generate important movement data, which can be analysed either manually or through computational methods.



## Challenges

- It is still difficult to find datasets of body movement data
- The existing ones do not include movements specific to the neuromotor rehabilitation context;
- Defining and structuring the data generated during the rehabilitation sessions.

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- Framework for creating Virtual Reality (VR) and Augmented Reality (AR) applications for the neuromotor rehabilitation area;
- The user's movement data is stored in a solution specifically designed for this purpose;
- Only the data regarding the user's joints is stored
  - More storage-efficient than video files;
  - Allows the movements to be replayed and analyzed from different angles and in different speeds;
  - The data is already discretized and normalized for the domain, enabling the application of machine learning approaches.
- Any body tracking device can be used;

# Methodology



The methodology of this work comprises three steps, executed simultaneously:

1. The design of the ReBase database;
2. The design of the **ReBase REST Server**;
3. The design **Unity ReBase** API

# ReBase Applications



- Three desktop applications were developed in Unity:
    1. *ReBase Session Recorder*;
    2. *ReBase Session Player*;
    3. *ReBase Session Manager*.

# ReBase Session Recorder


Figure: *ReBase Session Recorder*'s main screen during recording

# ReBase Session Player

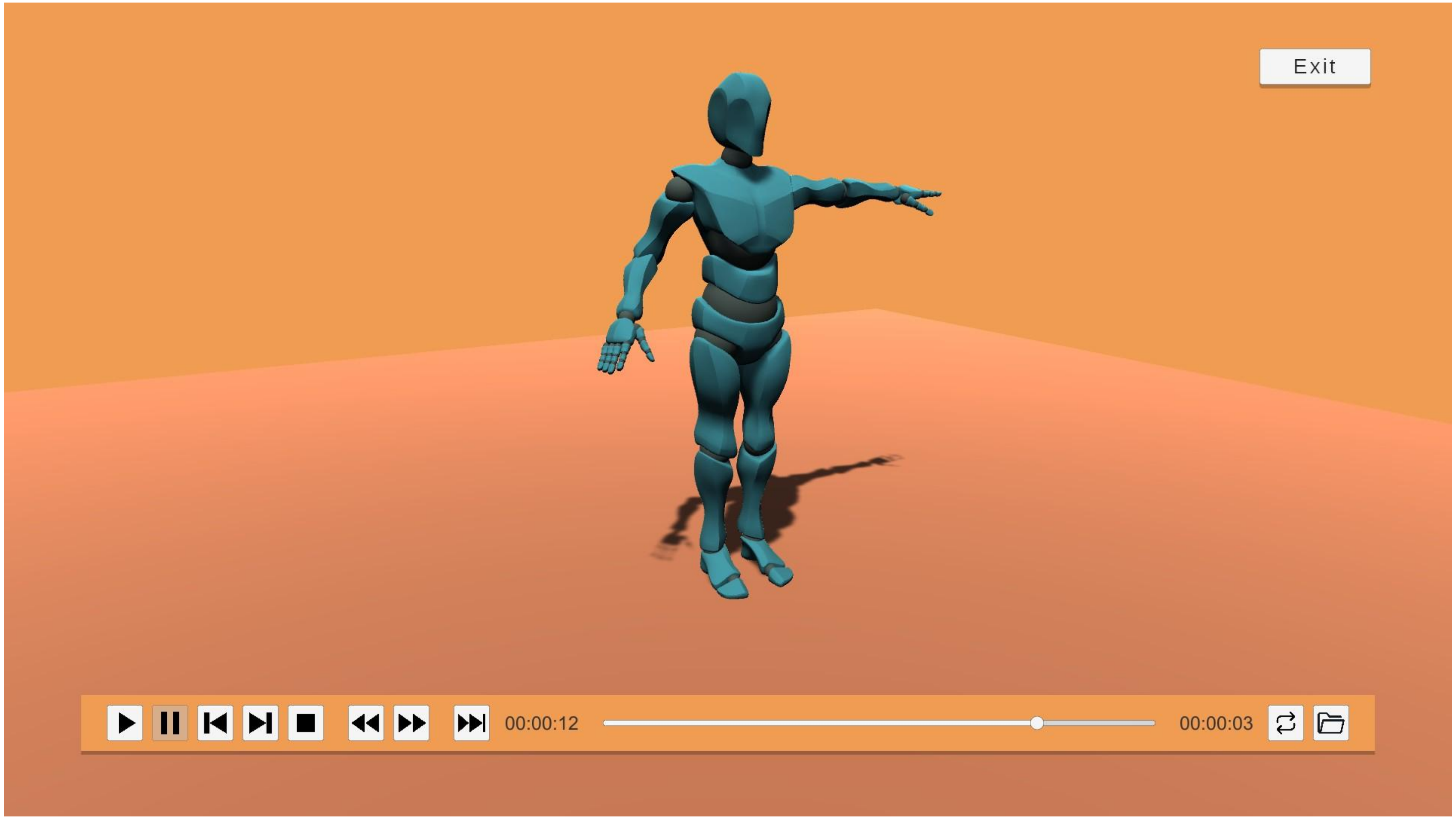


Figure: *ReBase Session Player*'s main playback screen

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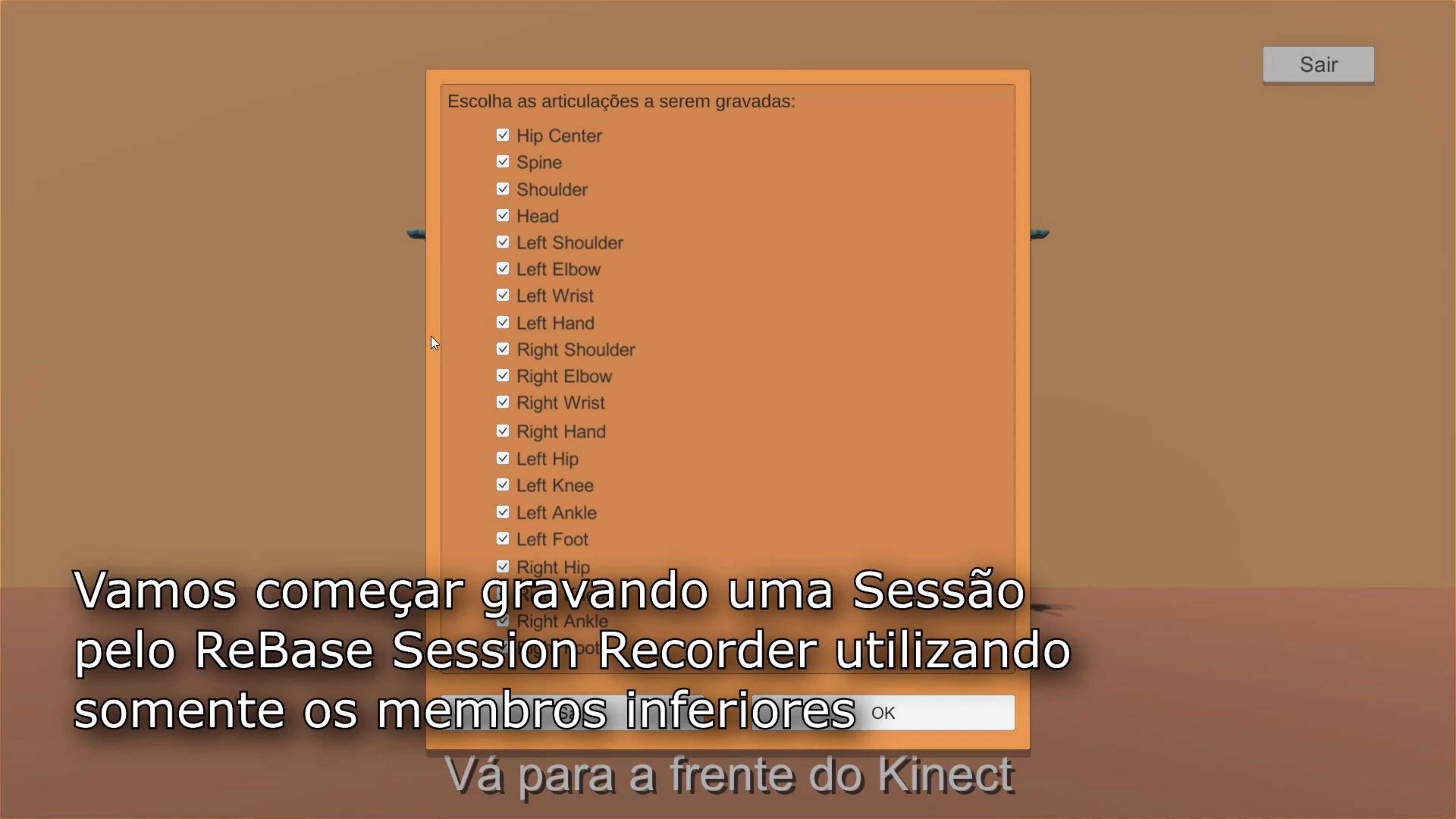
# ReBase Session Manager


Figure: *ReBase Session Manager*'s main menu with an expanded entry


Sair
Escolha as articulações a serem gravadas:
Hip Center
Spine
Shoulder
Head
Left Shoulder
Left Elbow
Left Wrist
Left Hand
Right Shoulder
Right Elbow
Right Wrist
Right Hand
Left Hip
Left Knee
Left Ankle
Left Foot
Right Hip
Right Ankle
OK
Vamos começar gravando uma Sessão pelo ReBase Session Recorder utilizando somente os membros inferiores
Vá para a frente do Kinect

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# Outras pesquisas...

- Rastreamento corporal de baratas (UNIFESP - 2023)
- Rastreamento corporal de cabras (UFSJ – CNPQ - 2024)
- Análise comportamental de abelhas (UNESP - 2024)
- Técnicas de XAI aplicadas a sistemas especialistas (UFSJ - 2024)

# Parceiros de Pesquisa

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