

# Computer vision and facial recognition

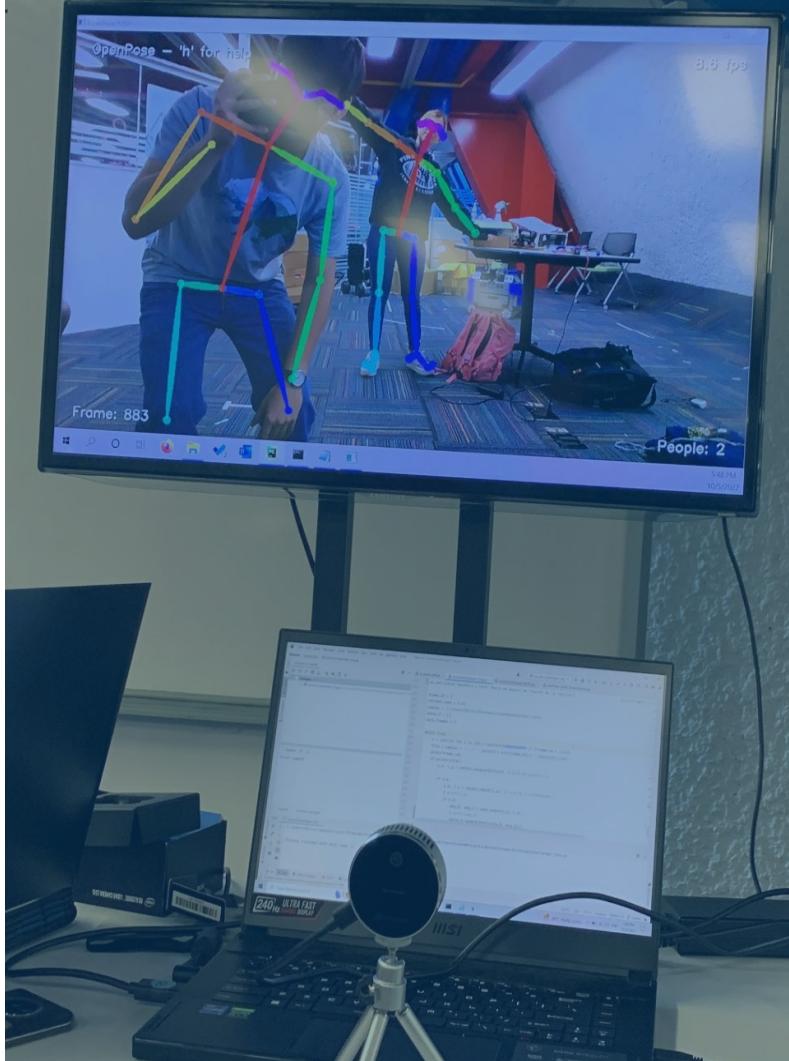
What is computer vision?, history, and study cases

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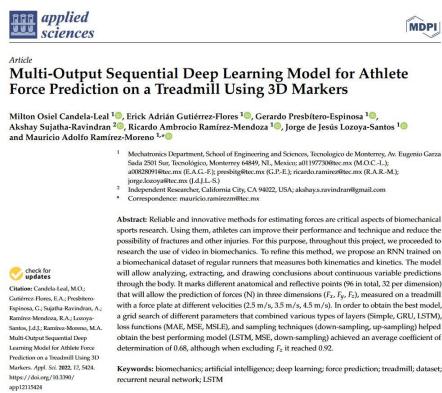
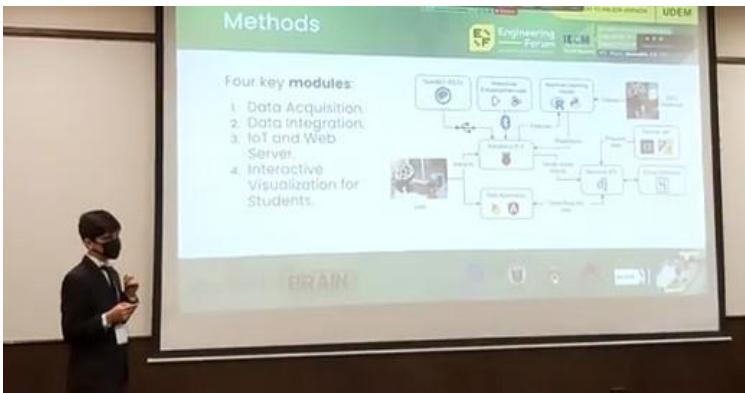


# Milton Osiel Candela Leal

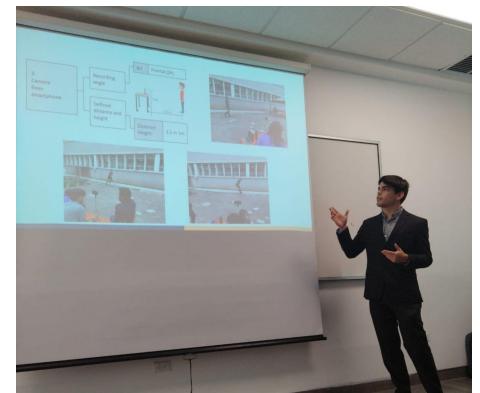
Biomedical Engineer

+2 Experience in an international research group at the Tec center:

- Building Reliable Advances and Innovations in Neurotechnology (BRAIN)
- +12 Coursera specializations in fields of Data Science, Artificial Intelligence, Machine Learning, Deep Learning
- Wearables and biometrics signal processing (EEG, ECG), as well as Computer Vision (CV) to predict features
- 8 scientific publications in MDPI, IEEE, and IEOM (2 journal, 5 conference proceedings, 1 book chapter)



[2022] 1<sup>st</sup> journal paper as lead author (MDPI)



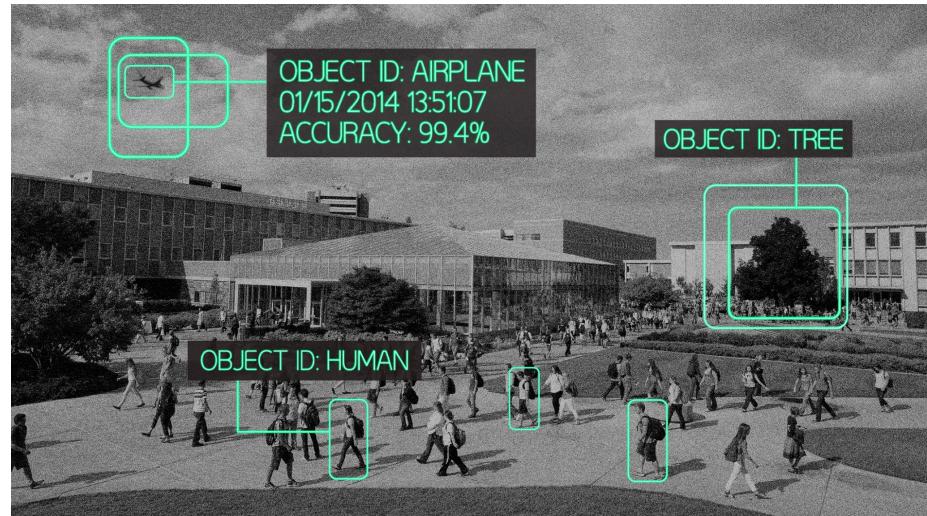
[2023] Educational Innovation Workshop (IEEE)

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## ¿Qué es visión computacional?

Es un área de la inteligencia artificial (IA) en la que los sistemas de software se diseñan para percibir el mundo visualmente, mediante cámaras, imágenes y vídeo (Microsoft)

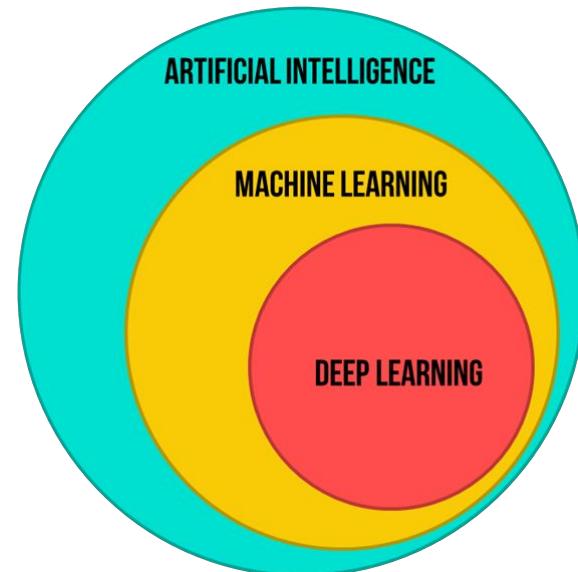
Es un campo de la IA que permite que las computadoras y los sistemas obtengan información significativa de imágenes digitales, videos y otras entradas visuales, y tomen acciones o hagan recomendaciones basadas en esa información (IBM)



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# IA vs ML vs DL

- AI: *Programs that can sense, reason, act and adapt*  
Bayesian methods, nearest neighbour, ...
- ML: *Algorithms that learn patterns in data over time*  
MLR, RF, SVM, LDA, XGBoost, kNN
- DL: *Deep multilayered neural networks that learn from **big data***  
ANN, CNN, LSTM, RNN, GANs



# Aplicaciones

- Automotriz
- Salud
- Agricultura
- Deporte
- Vigilancia
- Manufactura

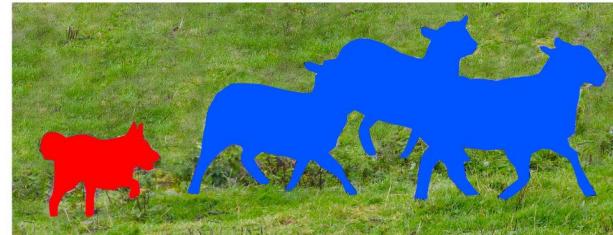


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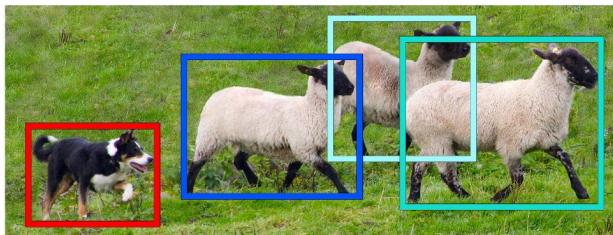
# Variantes



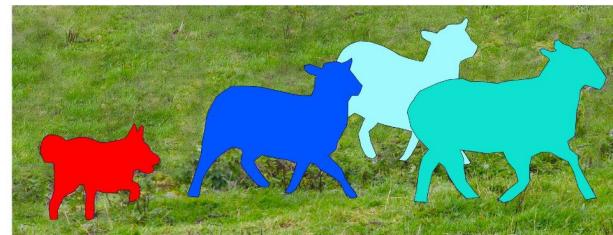
Image Recognition



Semantic Segmentation

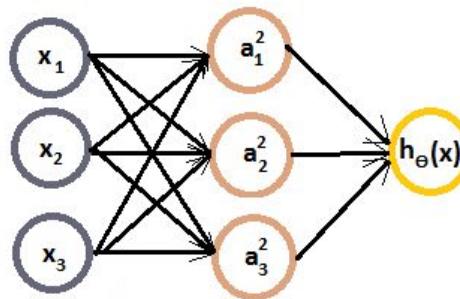
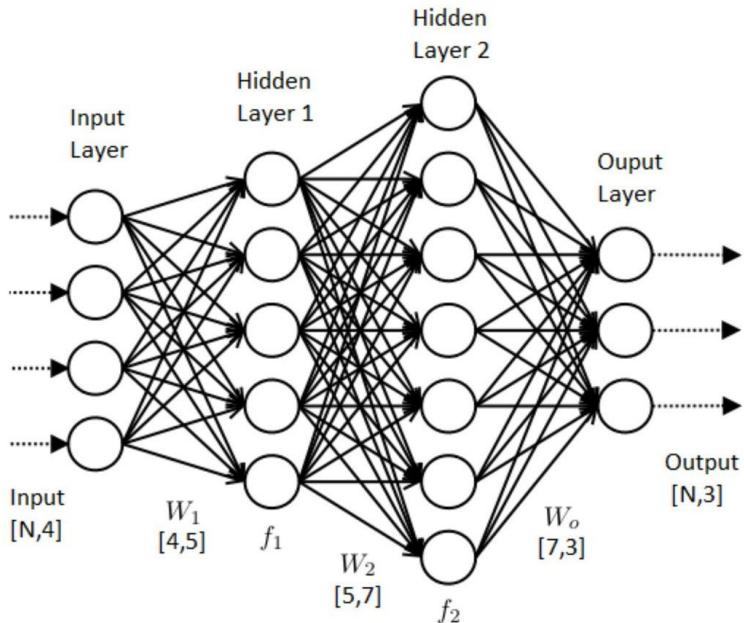


Object Detection



Instance Segmentation

# Red neuronal artificial (ANN)



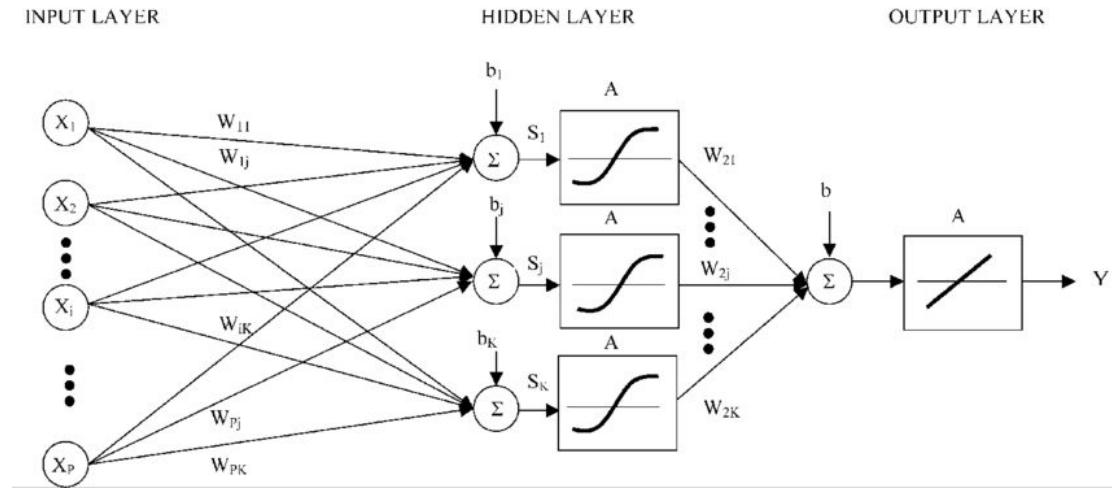
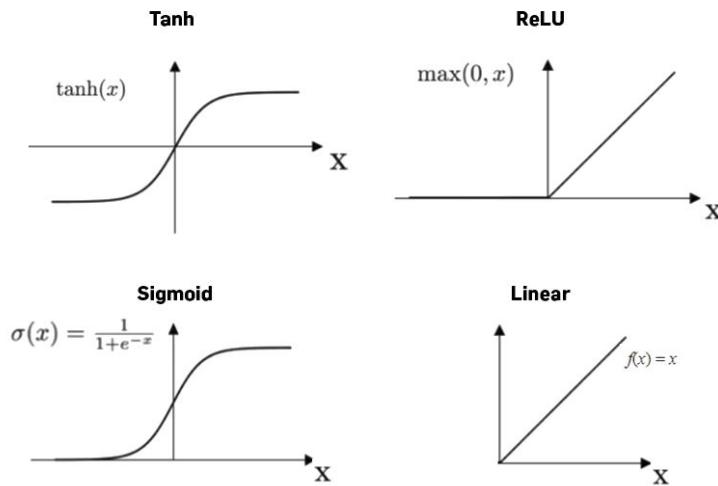
$$a_1^{(2)} = g(\Theta_{10}^{(1)}x_0 + \Theta_{11}^{(1)}x_1 + \Theta_{12}^{(1)}x_2 + \Theta_{13}^{(1)}x_3)$$

$$a_2^{(2)} = g(\Theta_{20}^{(1)}x_0 + \Theta_{21}^{(1)}x_1 + \Theta_{22}^{(1)}x_2 + \Theta_{23}^{(1)}x_3)$$

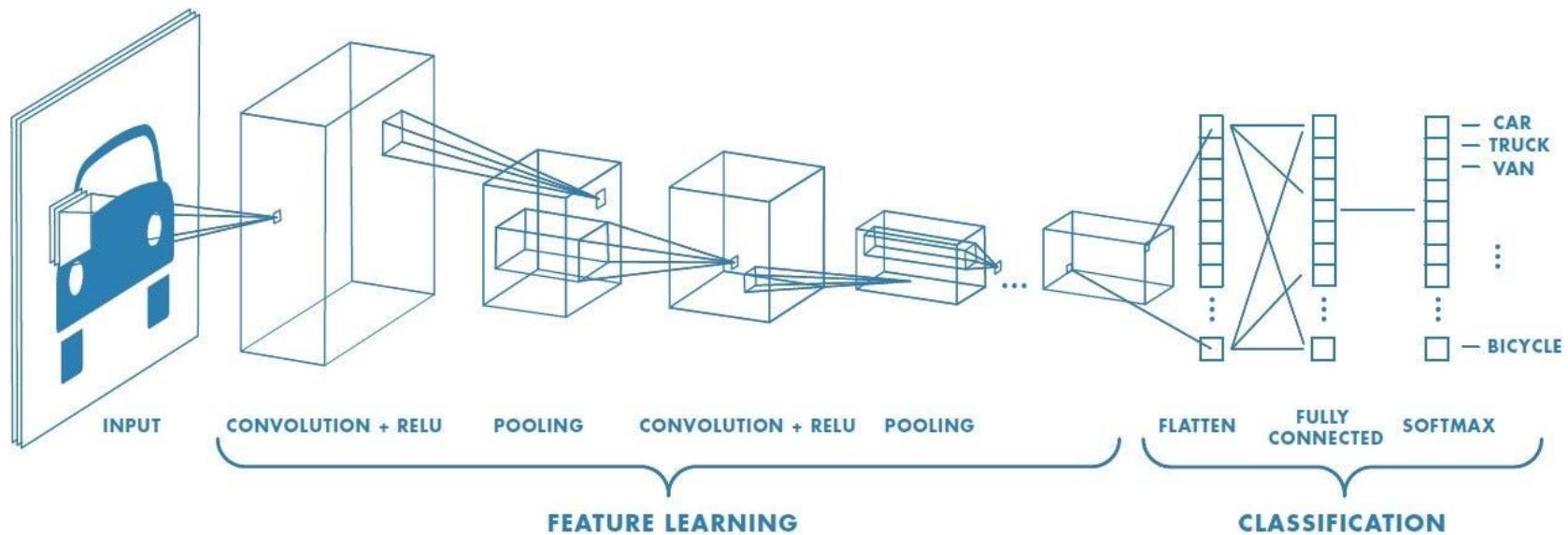
$$a_3^{(2)} = g(\Theta_{30}^{(1)}x_0 + \Theta_{31}^{(1)}x_1 + \Theta_{32}^{(1)}x_2 + \Theta_{33}^{(1)}x_3)$$

$$h_{\Theta}(x) = a_1^{(3)} = g(\Theta_{10}^{(2)}a_0^{(2)} + \Theta_{11}^{(2)}a_1^{(2)} + \Theta_{12}^{(2)}a_2^{(2)} + \Theta_{13}^{(2)}a_3^{(2)})$$

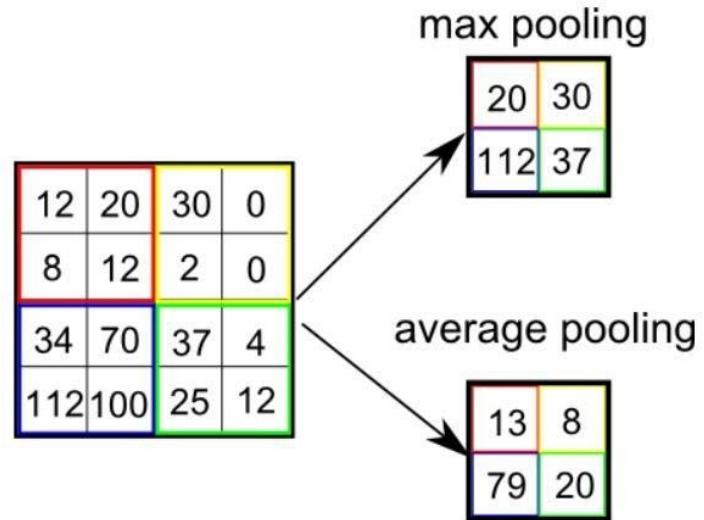
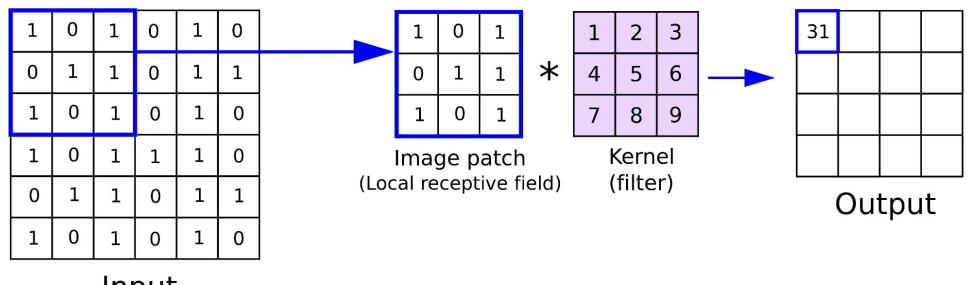
# Funciones de activación



# Red neuronal convolucional (CNN)



# Convolución y pooling



# Ejemplo de convolución

Enfoque

$$\begin{bmatrix} 0 & -1 & 0 \\ -1 & 5 & -1 \\ 0 & -1 & 0 \end{bmatrix}$$

Desenfoque

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & 1 & 1 \\ 1 & 1 & 1 \end{bmatrix}$$

Realce de bordes

$$\begin{bmatrix} 0 & 0 & 0 \\ -1 & 1 & 0 \\ 0 & 0 & 0 \end{bmatrix}$$

Repujado

$$\begin{bmatrix} -2 & -1 & 0 \\ -1 & 1 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

Detección de bordes

$$\begin{bmatrix} 0 & 1 & 0 \\ 1 & -4 & 1 \\ 0 & 1 & 0 \end{bmatrix}$$

Filtro de tipo Sobel

$$\begin{bmatrix} -1 & 0 & 1 \\ -2 & 0 & 2 \\ -1 & 0 & 1 \end{bmatrix}$$

Filtro de tipo Sharpen

$$\begin{bmatrix} 1 & -2 & 1 \\ -2 & 5 & -2 \\ 1 & -2 & 1 \end{bmatrix}$$

Filtro Norte

$$\begin{bmatrix} 1 & 1 & 1 \\ 1 & -2 & 1 \\ -1 & -1 & -1 \end{bmatrix}$$

Filtro Este

$$\begin{bmatrix} -1 & 1 & 1 \\ -1 & -2 & 1 \\ -1 & 1 & 1 \end{bmatrix}$$

Filtro de tipo Gauss

$$\begin{bmatrix} 1 & 2 & 3 & 1 & 1 \\ 2 & 7 & 11 & 7 & 2 \\ 3 & 11 & 17 & 11 & 3 \\ 2 & 7 & 11 & 7 & 1 \\ 1 & 2 & 3 & 2 & 1 \end{bmatrix}$$

- Repujado

Imagen original



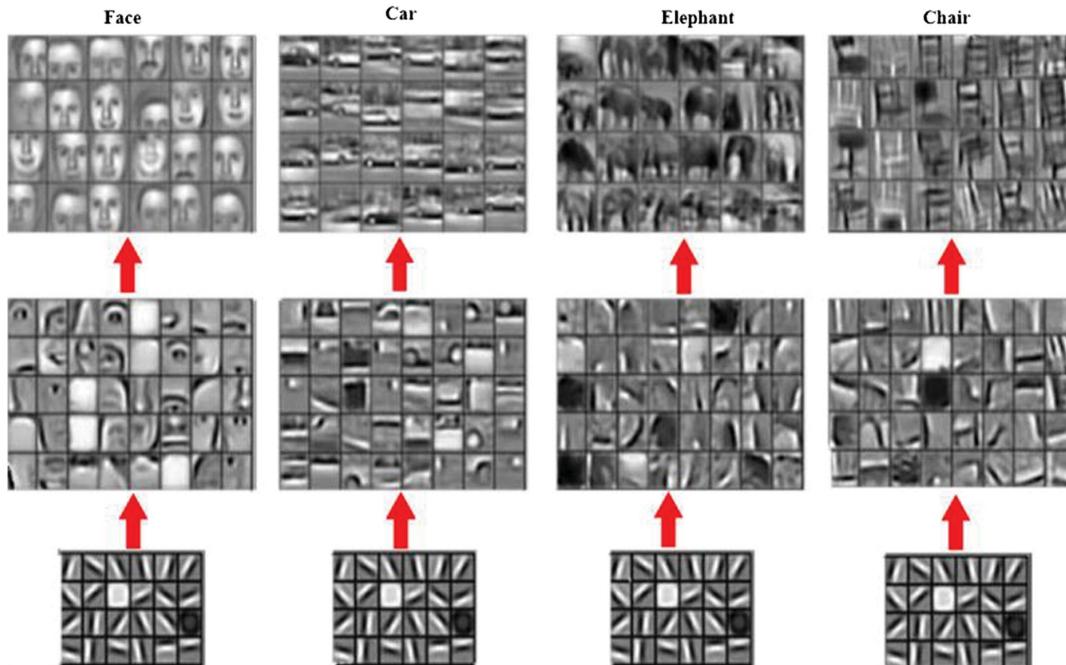
Imagen modificada



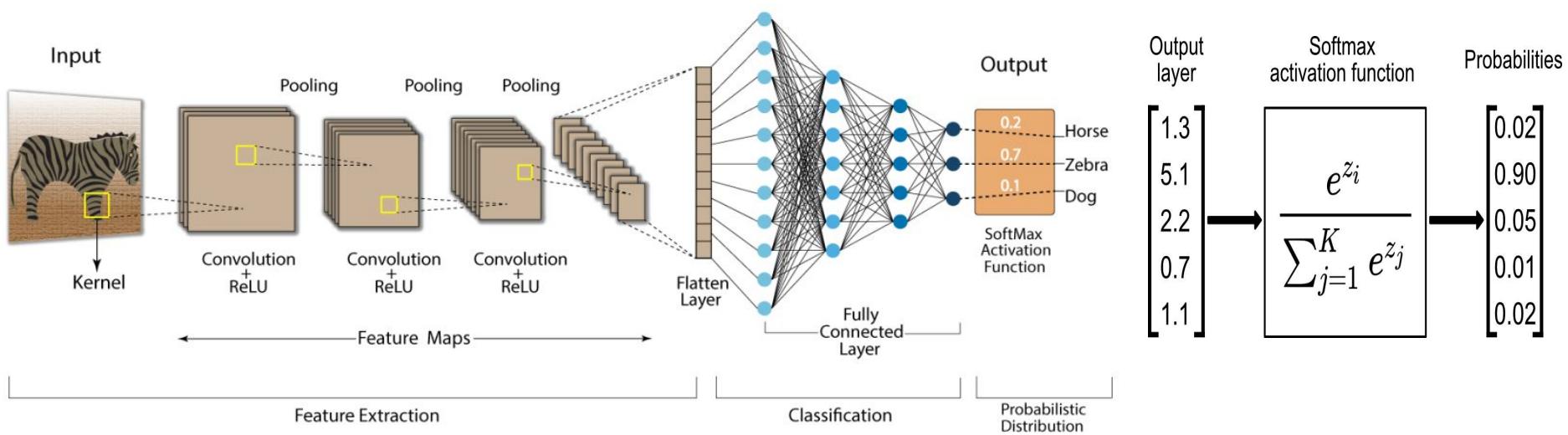
$$\begin{bmatrix} -2 & -1 & 0 \\ -1 & 1 & 1 \\ 0 & 1 & 2 \end{bmatrix}$$

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# Adquisición de características



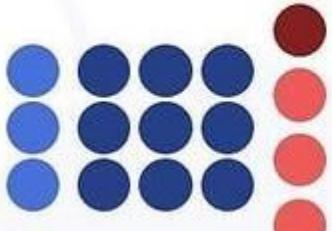
# Ejemplo de CNN para clasificación



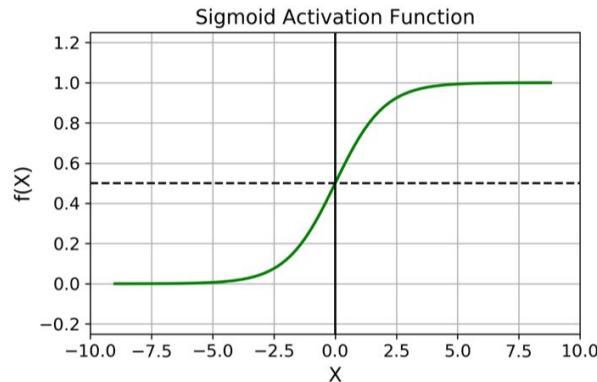
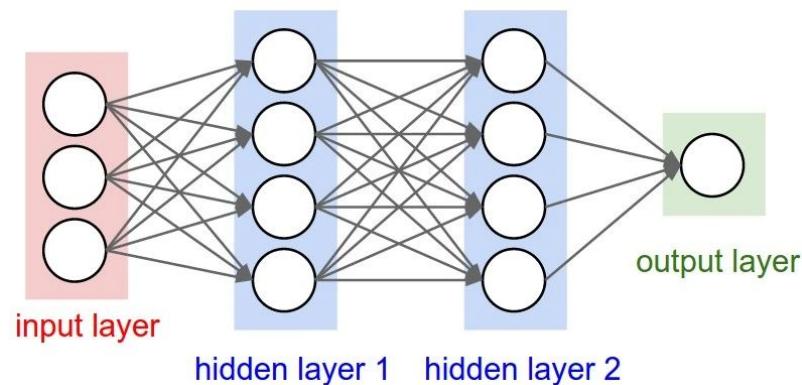
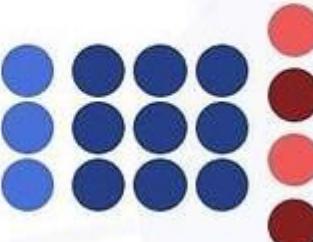
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# Tipos de output

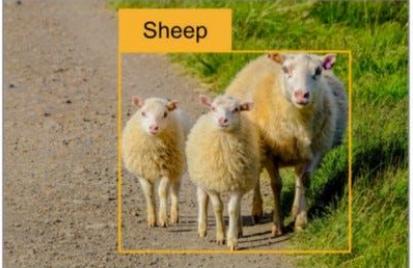
Multi-Class



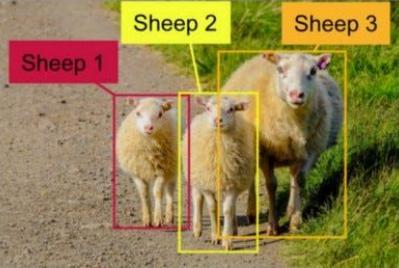
Multi-Label



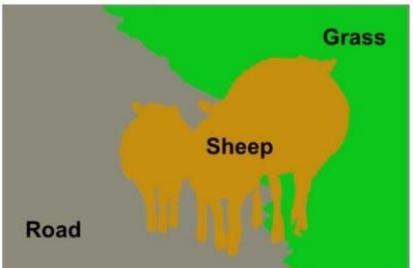
# Variantes



Classification + Localization

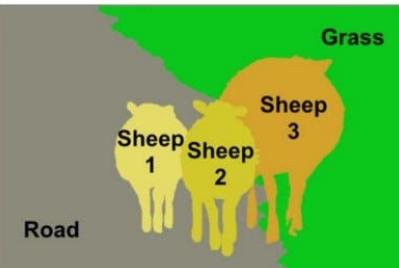


Object Detection



Road

Sheep



Road

Sheep  
1  
2

Sheep  
3

Semantic Segmentation

Instance Segmentation

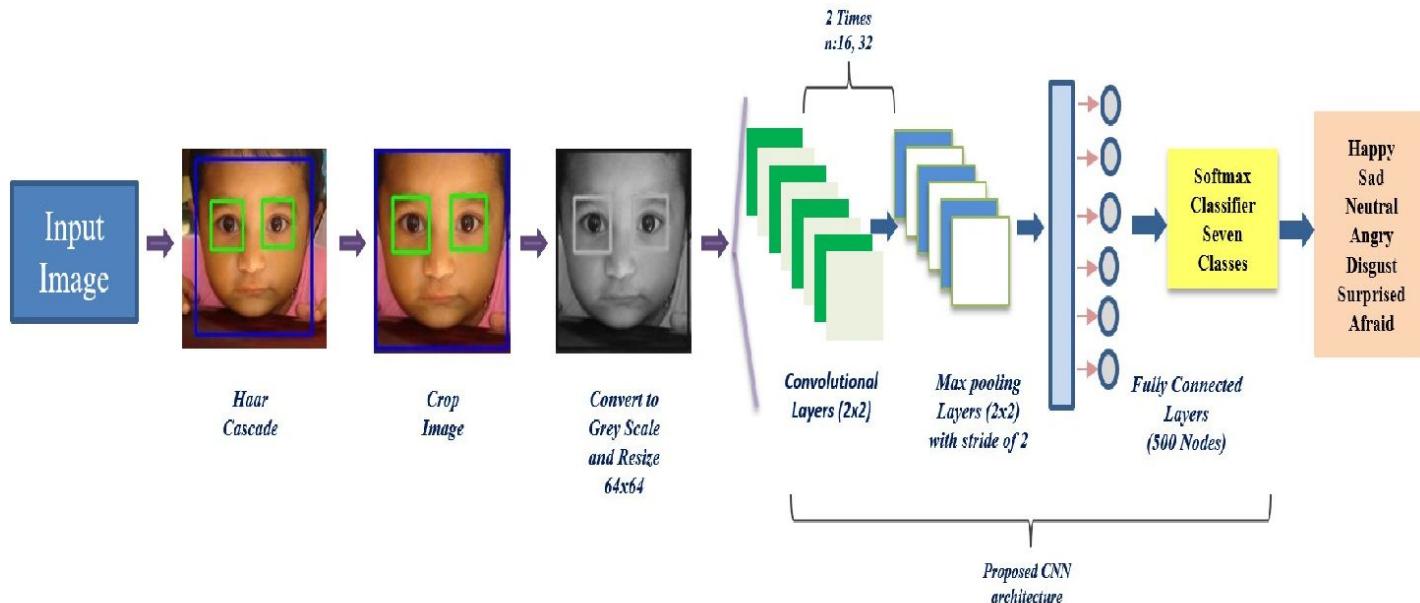


No Thanks

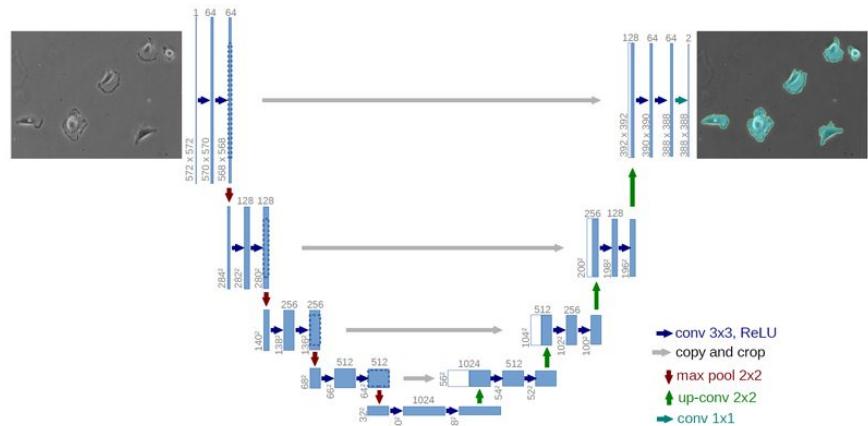
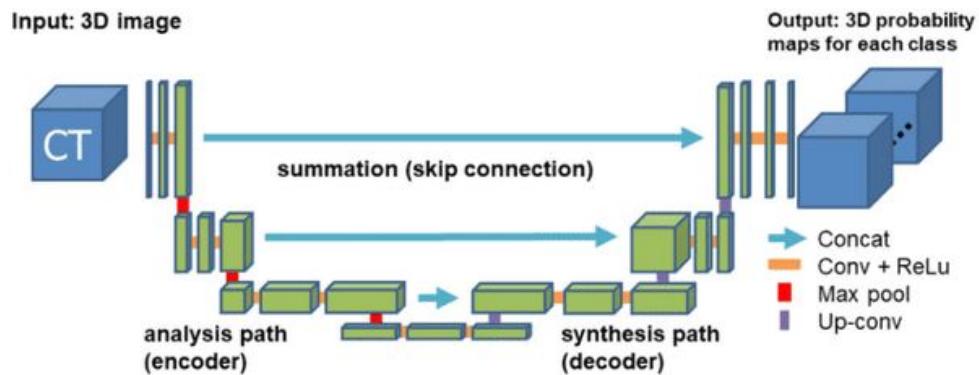
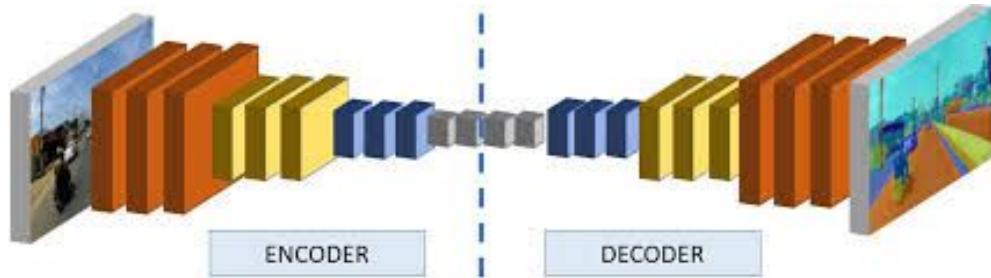


No Thanks

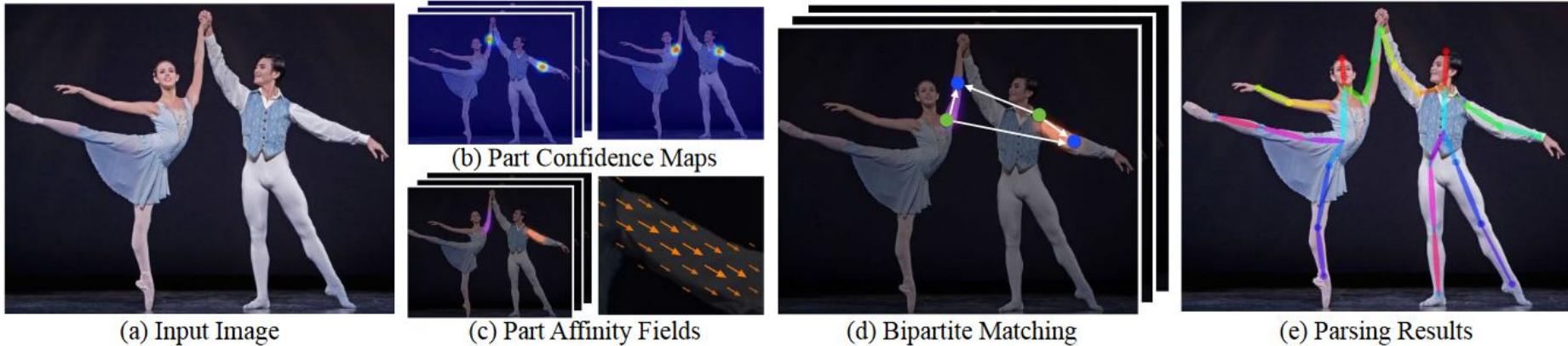
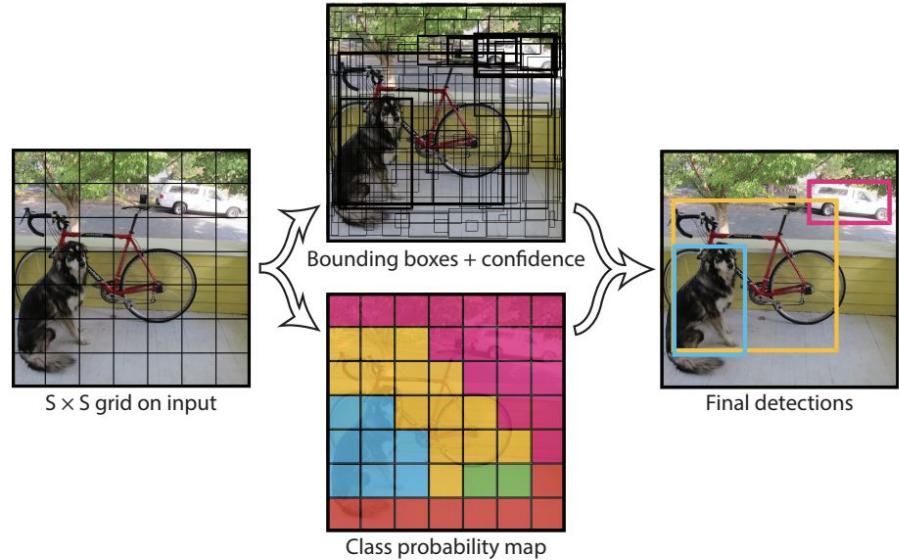
# Reconocimiento facial



# U-Net



# YOLO & OpenPose



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# Herramientas utilizadas

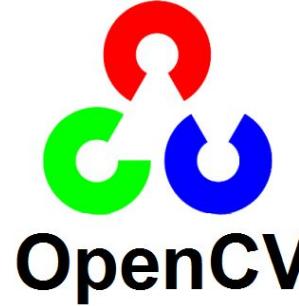
## Cámaras

- Intel RealSense L515
- Intel RealSense D435i



## Software

- Intel RealSense SDK
- OpenPose
- DeepFace
- OpenCV



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# Índice de proyectos

1. Biomechanics for the Digital Twin of Performance
2. Ángulo de Flexión de la Rodilla en Tiempo Real para Lesión de Ligamento Cruzado Anterior mediante Visión Computacional
3. Biomechanics Digital Twin: Markerless Joint Acceleration prediction using Machine Learning and Computer Vision (Artículo de conferencia)
4. Detección del interés en ingeniería en niños mediante un sistema inteligente de señales biométricas
5. Digital Twin modelling for Human Biomechanics and Office Spaces



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# Biomechanics for the Digital Twin of Performance

Study Cases

# Abstract

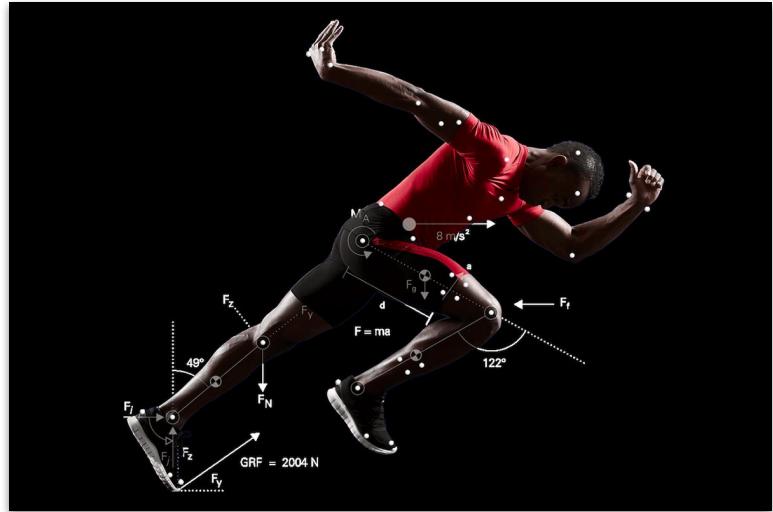
- This project focuses on movement tracking through video analysis to estimate acting forces on the body, with the aim of detecting risk of fracture for each joint in the human body.
- The automatic digitization of humans' joints as key points via CV algorithms, together with biomechanical-related biometrics given by wearables, is capable of creating a markerless DT for biomechanical assessment.





# Biomechanics

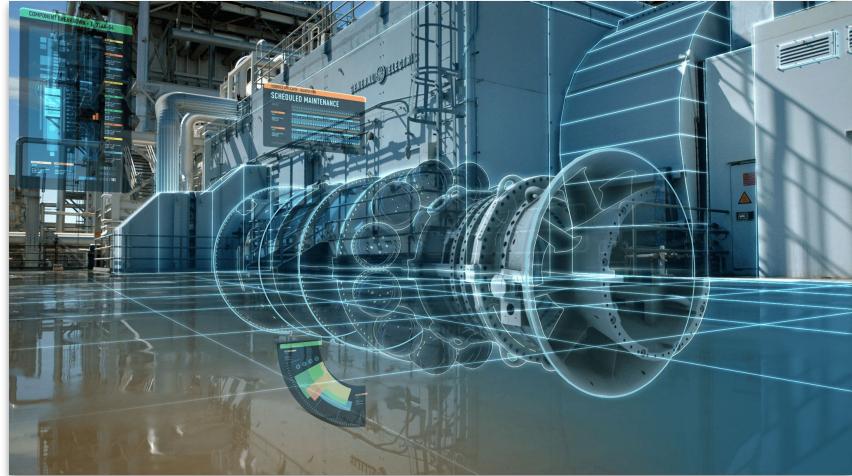
- It is the scientific study of the physical movement and structure of living creatures (Oxford University Press, 2021), often in humans referred to as the study of how the skeletal and musculature systems work under different conditions (What is Biomechanics? - Definition & Applications, 2016)





# Digital Twin

- A Digital Twin is a virtual model of physical assets, which continually learn and provide data insights.
- Unlike traditional simulation models, Digital Twins benefit from real-time data, which is fed into its virtual environment.



# Introduction

- Biomechanic analysis has been used for distinct applications, such as gait analysis regarding certain illnesses compared to a normal gait
- Recently, its application to sports has been on the rise, used to design and develop safety gear in sports, improvement for techniques and also minimize risk of fracture in specific movements.
- In high-intensity sports, fatigue injuries compose 20% of the total injuries (Fredericson et al., 2006).





# Current problem

- Most of the current analysis on biomechanics are being done by consensus of multiple experts.
- Technology in this field is mainly composed of laboratory biometrics with markers attached.





# Digital Twin in healthcare

- A Healthcare Digital Twin (HDT) would need to collect data such as age, weight, height, ECG, blood pressure, diet, mood etc. by numerous Internet of Things (IoT) devices (Shengli, 2021).
- Currently, some of the main approaches have been its use in modeling and simulation of different situations, such as medical surgery training simulation and medical equipment design (Y. Liu et al., 2019)



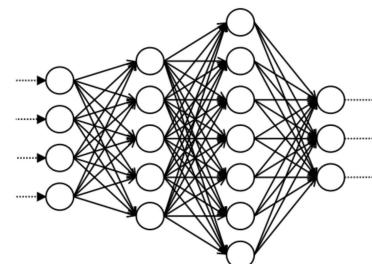
# Proposal

Input:

- XYZ acceleration of a person given by the wearables employed
- XY joint's positions given by a markerless CV model.
- Persons' metadata (Kg, Age)

Output:

- Biomechanical features (force, torque, angle, power) by each joint
- Risk of fracture coefficient



# Methodology - Manual digitization

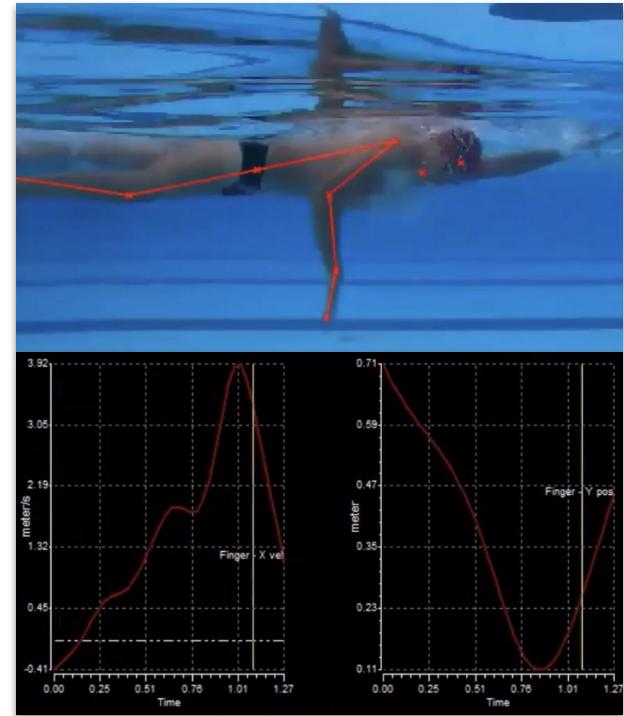
- Video selection

## **Skillspector**

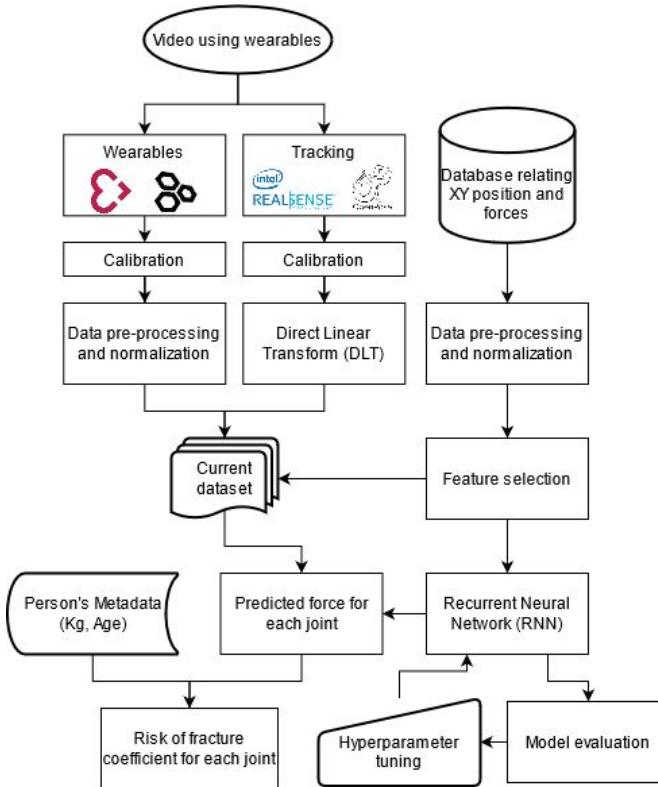
- Calibration of body position (for mapping video image coordinates to world space coordinates)
  - Profile selection
  - Height of person
- Manual digitization of body movement (tracking)
  - Profile selection (previously created small database)
  - Points to be digitized
- Graphs of dynamical elements in specific points e.g. velocity and acceleration on x and y axis

## **Calculations**

- Estimation of forces depending on sport e.g. force analysis of foot in high kick for taekwondo



# Methodology - Automatic digitization





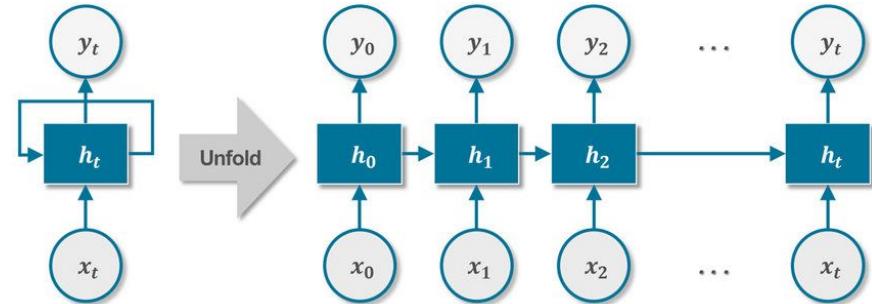
# OpenPose

- A real-time multi-person system that detects up to 135 human keypoints (body, hand, facial and foot) on images and video.
- It is based on a Convolutional Neural Network (CNN) algorithm which does not require markers to track the movement of the human body.



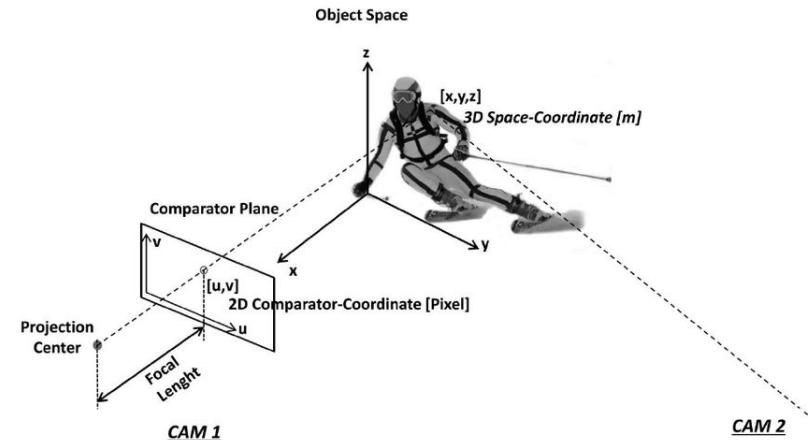
# Recurrent Neural Network

- A type of Artificial Neural Network (ANN) which uses sequential data.
- Unlike others ANNs, these have memory and so past inputs influence new inputs and outputs.
- Their applications are mainly Natural Language Processing (NLP) and time-series forecasting.



# Direct linear transform

- Using a set of control points already known, it can determine the 3D location of an object.
- Compute a fundamental matrix, used:
  - Projective transformation
  - Image rectification
  - Projective invariants
  - Outlier detection
  - Stereo matching

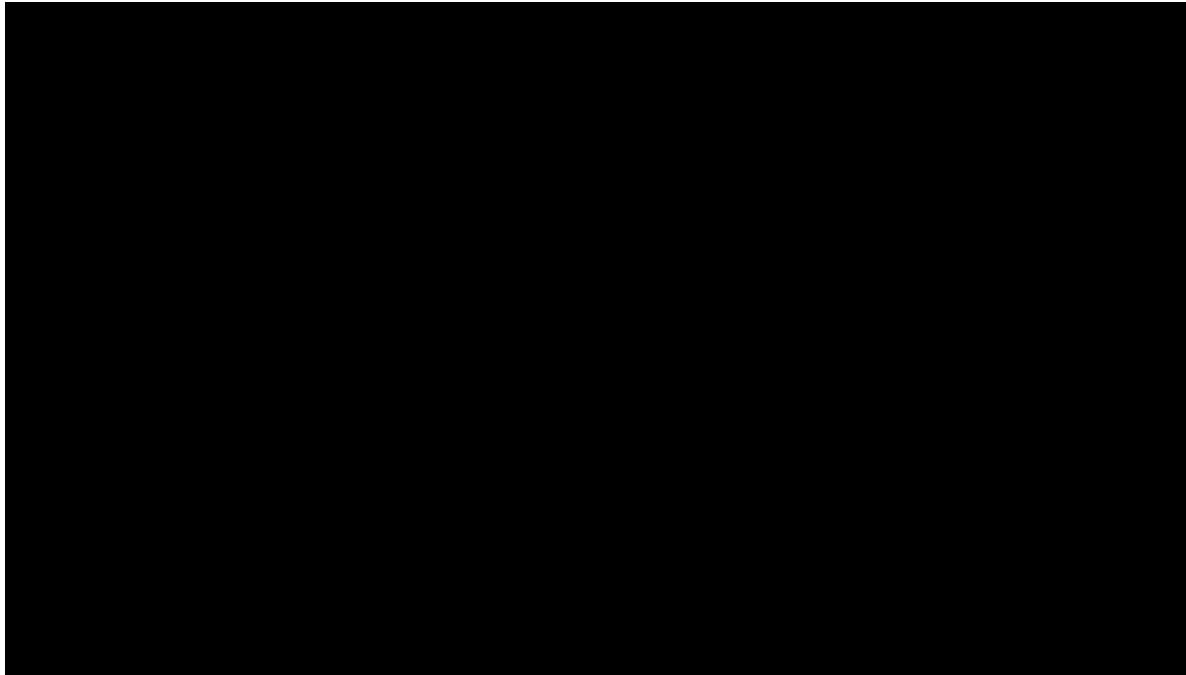




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# Manual digitization using web videos

## Swimming

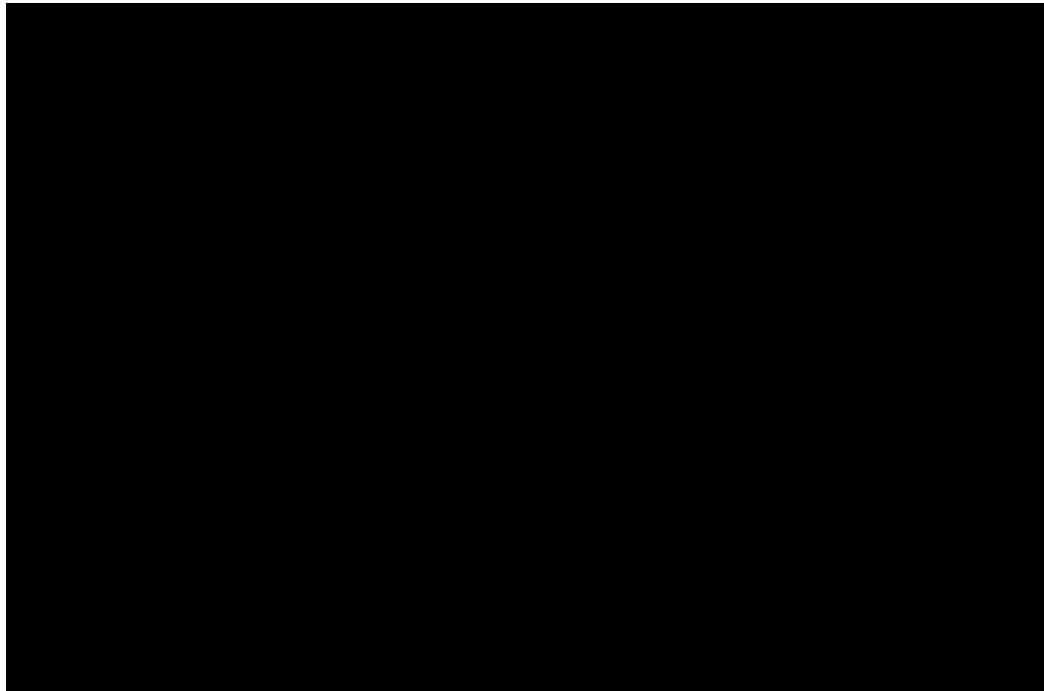




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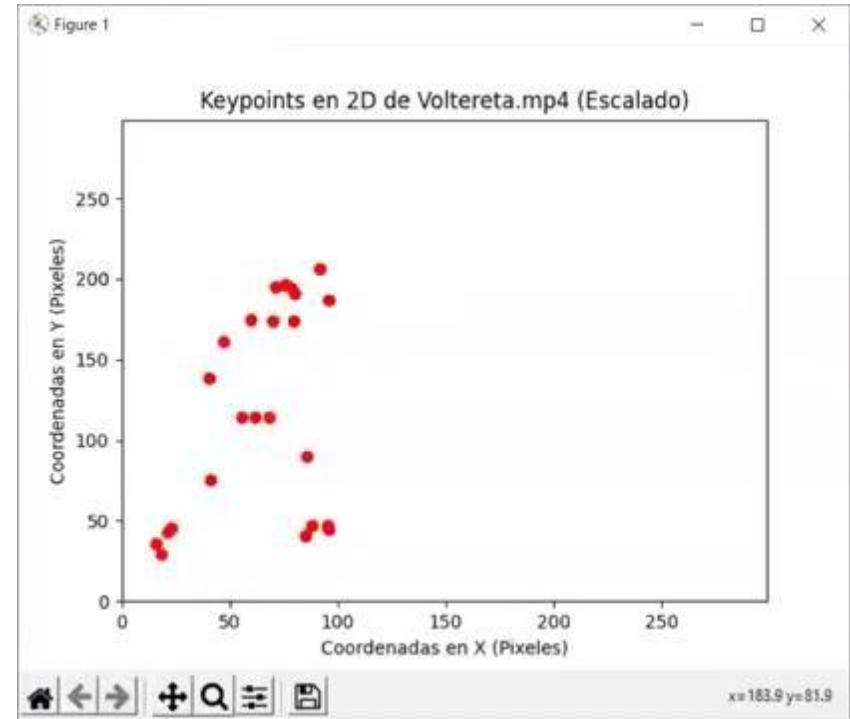
# Manual digitization using web videos

## Taekwondo



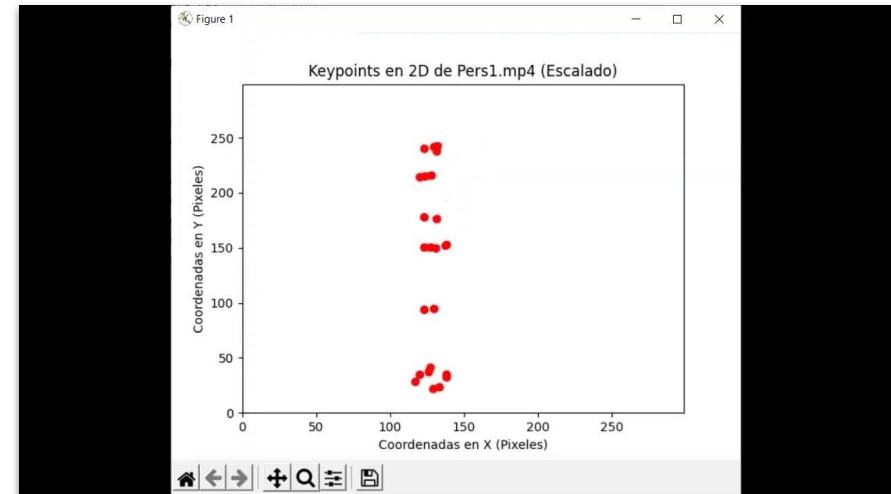


# Automatic digitization using web videos





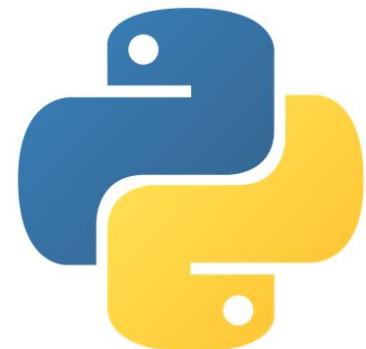
# Automatic digitization using our own videos





# Next steps

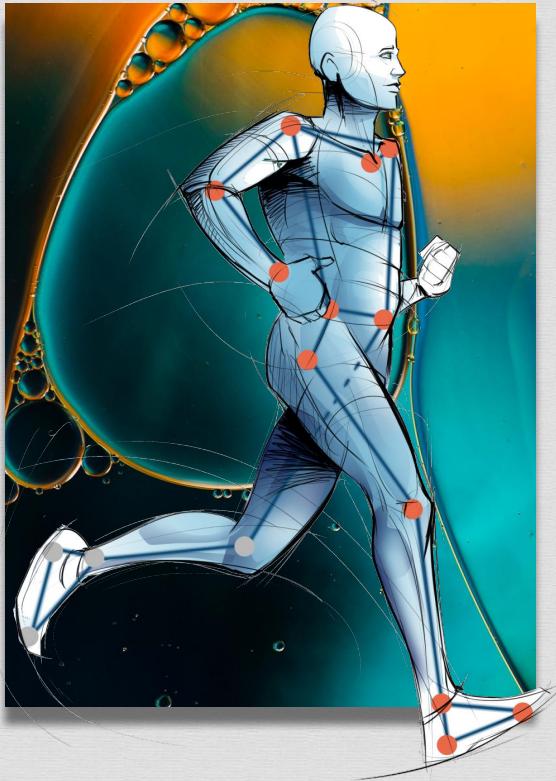
- Recurrent Neural Network (RNN) training using a database
- Automation of OpenPose/Intel analysis using its API for Python
- The use of Direct Linear Transformation (DLT) to calibrate
- Risk of fracture and biomechanical fractures prediction based on the RNN and person's metadata





# Conclusions

- Past investigations, which involve laboratory devices using markers, revealed that biomechanical features such as force, angles and torque could be extracted for each joint.
- Markerless tracking using software such as OpenPose and Intel® RealSense™ have shown promising results on estimating and predicting the position of humans' joints.
- Artificial intelligence and Machine Learning approaches, using wearables such as Hexiwear and Empatica E4, could only require calibration steps in order to predict the force, angles and torque, without the need of a laboratory device using attached markers.



# Ángulo de Flexión de la Rodilla en Tiempo Real para Lesión de Ligamento Cruzado Anterior mediante Visión Computacional

**Materia:** BI2004B.202 Análisis y Diseño en Biomecánica.

**Profesor Asesor:** Ing, Marcos David Moya Bencomo.

**Nombres de los participantes:**

- Valeria Estefani Esquivel Galvan.
- Milton Osiel Candela Leal

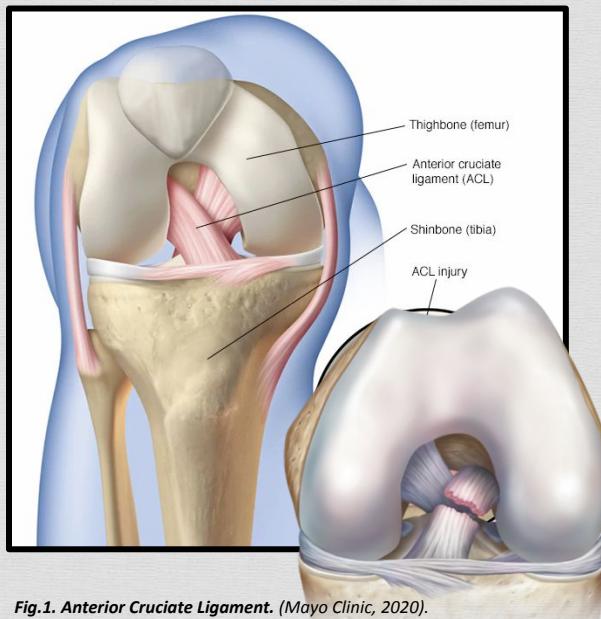
**Matrícula:**

- A00832596
- A01197730

# 1. Mecanismo de Ligamento Cruzado Anterior (LCA)

DE ACUERDO CON EL LCA...

“El ligamento cruzado anterior (LCA) se localiza dentro de la articulación de la rodilla. Una lesión de LCA se produce cuando el ligamento se estira o desgarra.” (Lamplot JD., 2020).



Funciones del ligamento cruzado anterior.

1. La función principal del ligamento cruzado anterior (LCA) es dar **estabilidad** anterior a la rodilla (articulación), tanto como rotatoria.
2. Conecta los huesos de la parte superior (**femur**) e inferior (**tibia**) de la pierna, **evita y limita** movimientos excesivos de rotación hacia delante de las mismas (hiperextensión).
3. Limita el **varo-valgo**, refiriéndose a **cargas**, la desalineación del eje de las rodillas desde un plano frontal.

Fig.1. Anterior Cruciate Ligament. (Mayo Clinic, 2020).

# 1. Mecanismos de Lesiones de Acuerdo al Ligamento Cruzado Anterior.

*Con base en lesiones (CINEMÁTICA)...*

Las **atletas femeninas** tienen un mayor riesgo relativo de lesión de sufrir un desgarro del LCA. (S. Schultz, R., Schmitz, A.D., Nguyen, A D. Padua, 2010).

De acuerdo con diferentes (factores) como...

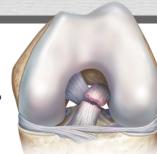
1. Biomecánicos

2. Hormonales

3. Anatómicos

**Mayor anteversión pélvica, ángulo Q y ángulo femorotibial, laxitud articular, masa y funciones musculares.**  
(S. Schultz, R., Schmitz, A.D., Nguyen, A D. Padua, 2010).

Rotación del fémur sobre una tibia fija (pie apoyado) durante un movimiento de valgo excesivo o forzado (pivot). **Sobrepasa su límite de tensión causando lesión.**



Movimiento

01



**Varo-valgo** (Distancia entre rodillas), **Peak Knee Flexion** (torsión, desaceleración mayor).



Desfiguraciones

02

Equilibrio, Movimiento inadecuado, Soporte Ineficiente.



Complicaciones / Límites

03

Fig.1.  
Ejemplificación  
de Varo-Valgo.  
(Tourne, E.,  
2018).

Normal (valgo fisiológico)

Genu valgo

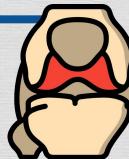
## 2. Metodologías de Diagnóstico de Lesiones (LCA)

*DIAGNÓSTICOS en base a prácticas tecnológicas y manuales.*

01

### → Maniobras Físicas de Diagnóstico.

De acuerdo con dolor, desbalance y límite de flexión/extensión.



#### Test de Lachman

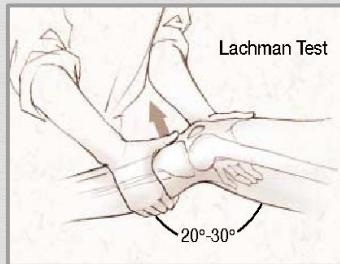


Fig. 1. Lachman Test. (Solomon, D.H., Simel, D.L., Bates, D., Katz, J.N., & Schaffer, J.L., 2001).

#### Prueba Pivot (Pivot Shift)

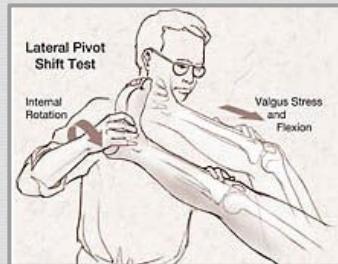


Fig. 2. Lateral Pivot Shift Test. (Solomon, D.H., Simel, D.L., Bates, D., Katz, J.N., & Schaffer, J.L., 2001).

La inestabilidad anterior de rodilla, se produce un incremento de la translación anterior de la tibia y de la rotación interna.

### Tecnológicas Actuales

02

#### Resonancia Magnética Nuclear (RMN).



Sensibilidad de 97% y especificidad alrededor de 87% para identificar lesiones de LCA. (N.J. Orlando, J. Yaqoob, R. Martin, 2015).

**Tomografías:** Daño óseo.

**Radiografías , Ultrasonidos:** Estáticos, combinación con evaluación dinámica. / Resultados confiables por medio de un Radiólogo.



## 2. Metodologías de Diagnóstico de Lesiones (LCA)

En base a nuestro objetivo...

Se atacará/**evitará** a la cinemática aberrante de la rodilla, la cual es indicativa de un **mayor riesgo de lesión del LCA** sin contacto en la **atleta femenina** [1] con protocolos de **prevención/monitoreo** de retroalimentación en tiempo real [2], al aprovechar herramientas tecnológicas de IA como VC para predecir rasgos biomecánicos [3].

01

Proceso de Medición / Enfoque



Se medirá:

1. Distancia entre rodillas, Minimum knee separation distance).
2. Peak Knee Flexion (torsión, desaceleración mayor).

ETAPAS DE ACUERDO A UNA LESIÓN:



**Medición:** OpenPose [4], Python, Cámara LiDAR Intel RealSense L515

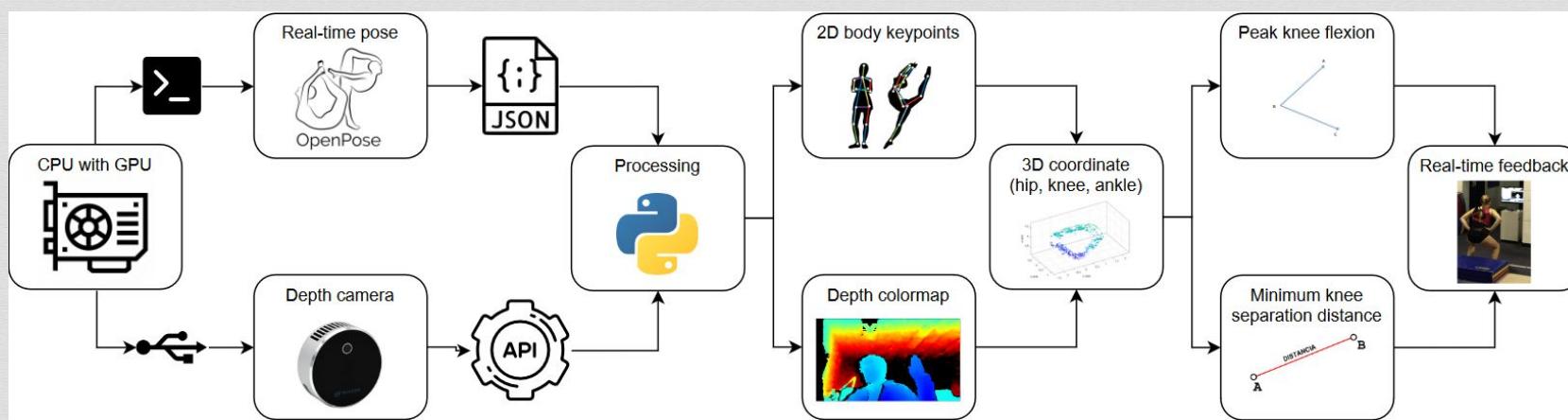
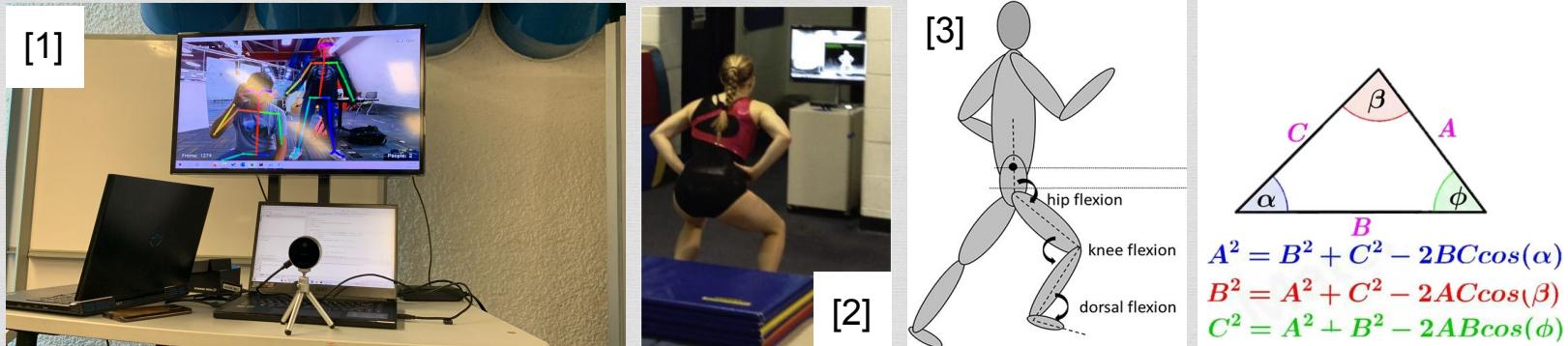


**Proyección:** Pantalla de televisor para retroalimentación al atleta



1. McAmis, N. E., Hardisty, A. V., Feinn, R. S., & Garbalosa, J. C. (2021). A comparison of kinematic demands placed on the knee and hip during two ACL return-to-sport screening maneuvers and an agility test. *Physical Therapy in Sport*, 52, 155–161. doi:10.1016/j.ptsp.2021.09.001
2. Nyman, E., & Armstrong, C. W. (2015). Real-time feedback during drop landing training improves subsequent frontal and sagittal plane knee kinematics. *Clinical Biomechanics*, 30(9), 988–994. doi:10.1016/j.clinbiomech.2015.06.018
3. Candela-Leal, M. O., Gutiérrez-Flores, E. A., Presbitero-Espinosa, G., Sujatha-Ravindran, A., Ramírez-Mendoza, R. A., Lozoya-Santos, J. de J., & Ramírez-Moreno, M. A. (2022). Multi-Output Sequential Deep Learning Model for Athlete Force Prediction on a Treadmill Using 3D Markers. *Applied Sciences*, 12(11). doi:10.3390/app12115424
4. Cao, Z., Hidalgo Martinez, G., Simon, T., Wei, S., & Sheikh, Y. A. (2019). OpenPose: Realtime Multi-Person 2D Pose Estimation using Part Affinity Fields. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.

### 3. Metodología para Evaluación Cuantitativa de la Lesión



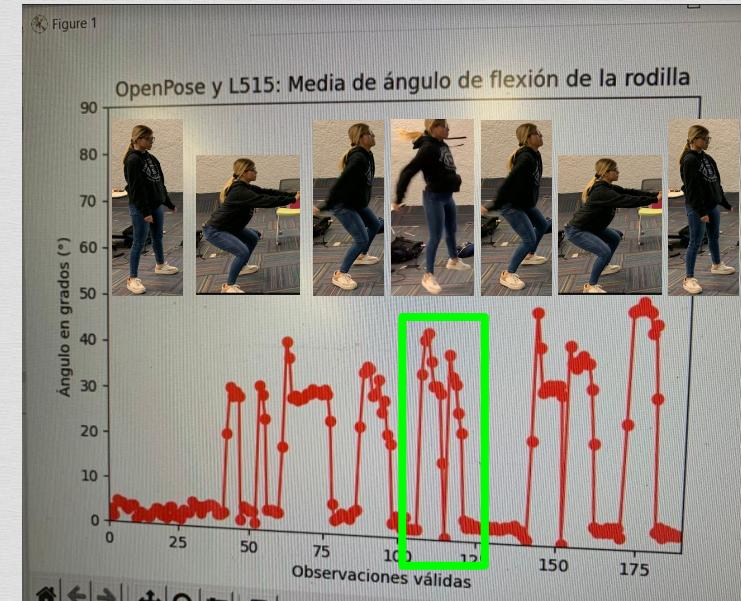
- Cao, Z., Hidalgo Martinez, G., Simon, T., Wei, S., & Sheikh, Y. A. (2019). OpenPose: Realtime Multi-Person 2D Pose Estimation using Part Affinity Fields. *IEEE Transactions on Pattern Analysis and Machine Intelligence*.
- Nyman, E., & Armstrong, C. W. (2015). Real-time feedback during drop landing training improves subsequent frontal and sagittal plane knee kinematics. *Clinical Biomechanics*, 30(9), 988–994. doi:10.1016/j.clinbiomech.2015.06.018
- Falch, H. N., Rædergård, H. G., & van den Tillaar, R. (2020). Effect of Approach Distance and Change of Direction Angles Upon Step and Joint Kinematics, Peak Muscle Activation, and Change of Direction Performance. *Frontiers in Sports and Active Living*, 2. doi:10.3389/fspor.2020.594567
- Sigward, S. M., Havens, K. L., & Powers, C. M. (2011). Knee Separation Distance and Lower Extremity Kinematics During a Drop Land: Implications for Clinical Screening. *Journal of Athletic Training*, 46(5), 471–475. doi:10.4085/1062-6050-46.5.471

# Resultados de Acuerdo con la Metodología de Software

- Incrementar ángulo de flexión de la rodilla al caer protege LCA [1]
- Mujeres con colapso en valgo tienden a tener menos ángulo de flexión de la rodilla [2]
- Ángulos de flexión de rodilla poco profundos ( $< 40^{\circ}$ - $60^{\circ}$ ), tensión de tracción en el LCA [3]



[https://drive.google.com/file/d/15-vduiXZdgwjiY8\\_zModmrTOOnCBD95wC/view](https://drive.google.com/file/d/15-vduiXZdgwjiY8_zModmrTOOnCBD95wC/view)



1. Ameer, M. A., & Muaidi, Q. I. (2017). Relation between peak knee flexion angle and knee ankle kinetics in single-leg jump landing from running: a pilot study on male handball players to prevent ACL injury. *The Physician and sportsmedicine*, 45(3), 337–343. <https://doi.org/10.1080/00913847.2017.1344514>
2. Shultz, S. J. (2008). Editorial. ACL Injury in the Female Athlete: A Multifactorial Problem That Remains Poorly Understood. *Journal of Athletic Training*, 43(5), 455–455. doi:10.4085/1062-6050-43.5.455
3. Demorat, G., Weinhold, P.S., Blackburn, T., Chudik, S.C., & Garrett, W.E. (2004). Aggressive Quadriceps Loading Can Induce Noncontact Anterior Cruciate Ligament Injury. *The American Journal of Sports Medicine*, 32, 477 - 483.

## 5. Justificación de Resultados

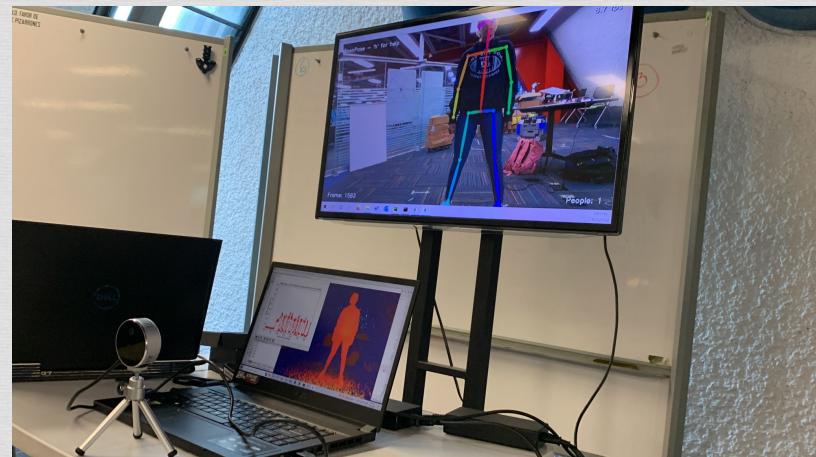
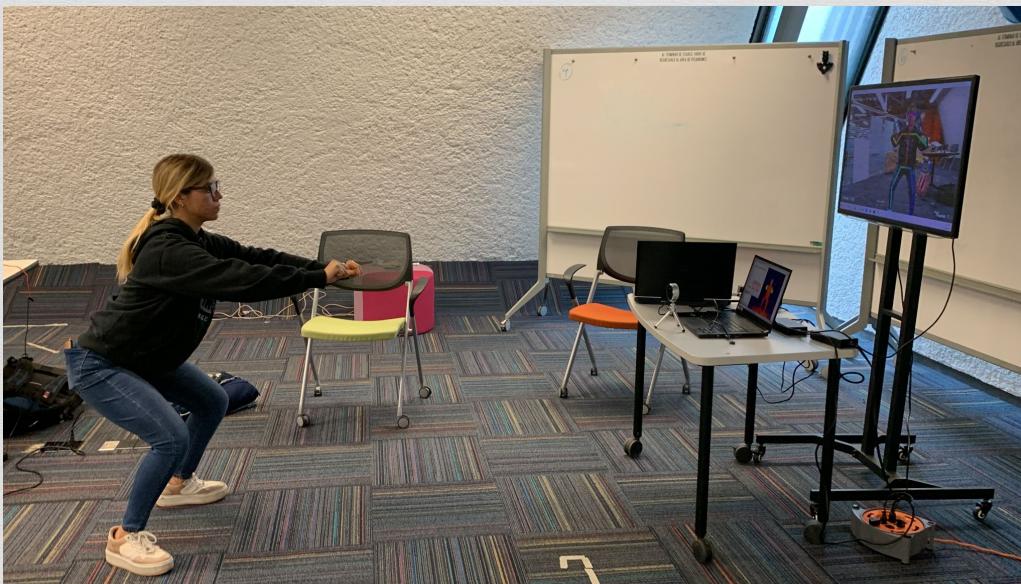
Intel RealSense L515 (30 fps)

- RGB 1920 x 1080
- Infrarrojo 1920 x 1080
- Depth 1024 x 768

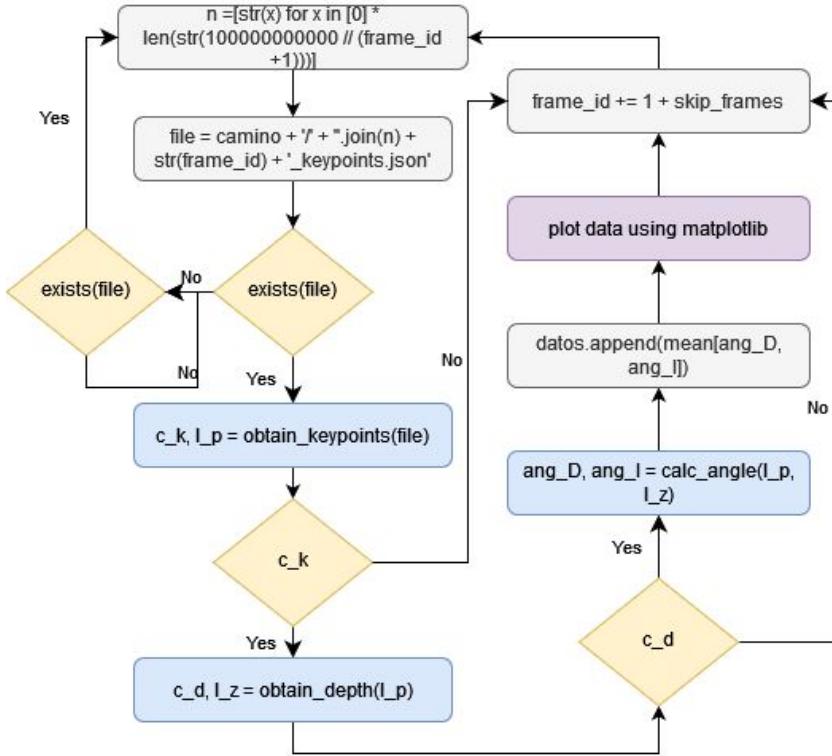
Re-escalado a 1024 x 768

Laptop

- RTX 3060 2 GB NVIDIA VRAM
- 16 GB RAM
- i7 Tiger Lake 2.30 GHz



# Main() function




---

**Algorithm 1** calc\_average\_knee\_flex\_angle( $r, s_f$ )

---

**Input**  $r$  es el radio de tolerancia para calcular profundidad.  
**Input**  $s_f$  son los frames saltados para análisis.

**Require:**  $r \geq 0 \vee s_f \geq 0$

- 1:  $n_f \leftarrow 1$
- 2: **while** TRUE **do**
- 3:    $f \leftarrow \text{file\_name}(n_f)$
- 4:   **if** file\_exists( $f$ ) **then**
- 5:      $c_k, l_p \leftarrow \text{obtain\_keypoints}(f)$
- 6:     **if**  $c_k$  **then**
- 7:        $c_d, l_z \leftarrow \text{obtain\_depth}(l_p)$
- 8:       **if**  $c_d$  **then**
- 9:          $\theta_D, \theta_I \leftarrow \text{calc\_angle}(l_p, l_z)$
- 10:          $\theta \leftarrow (\theta_D + \theta_I)/2$
- 11:         save\_data( $\theta$ )
- 12:         plot\_data( $\theta$ )
- 13:       **end if**
- 14:     **end if**
- 15:      $n_f \leftarrow n_f + s_f + 1$
- 16:   **else**
- 17:     **while** !exists( $f$ ) **do**
- 18:       wait
- 19:     **end while**
- 20:   **end if**
- 21: **end while**

---



# Biomechanics Digital Twin: Markerless Joint Acceleration prediction using Machine Learning and Computer Vision

## Education Innovation 2023

*Data in Action: Digital Ecosystem and Emerging Tools for Education*

Undergraduate Students:

Milton Osiel Candela Leal, Dacia Martínez Díaz, Cecilia Orozco Romo, Aime Judith Aguilar Herrera, Jesús Eduardo Martínez Herrera, Arath Emmanuel Marín Ramírez, Luis Orlando Santos Cruz, César Francisco Cruz Gómez, Santiago Xavier Carrillo Ruiz, Erick Adrián Gutiérrez Flores, Karen Lizette Rodríguez Hernández, Esther Aimeé Delgado Jiménez,

Professors:

Gerardo Presbítero Espinosa, Mauricio Adolfo Ramírez Moreno, Jorge de Jesús Lozoya Santos.

## General Context

The **study of body movement** has helped analyze various fields of study, among which exercise science, sport performance and kinesiology stand out, fields in which there is a high risk of injury in high-performance activities, specifically a **high incidence of injuries and fractures due to fatigue or stress**.

The **focus** of the study is the use of technology to develop tools that help people identify **risk factors** in their body movements that can compromise their overall health and well-being.





## Problem Statement

For athletes, coaches, or people in rehabilitation, 3D camera systems and **lab configuration** could be financially, logically, and organizationally **limiting**.

In addition, the **general analysis** presents its own **complications** for coaches in the sport, since technical experts and the consensus formed by them are needed to interpret the results.





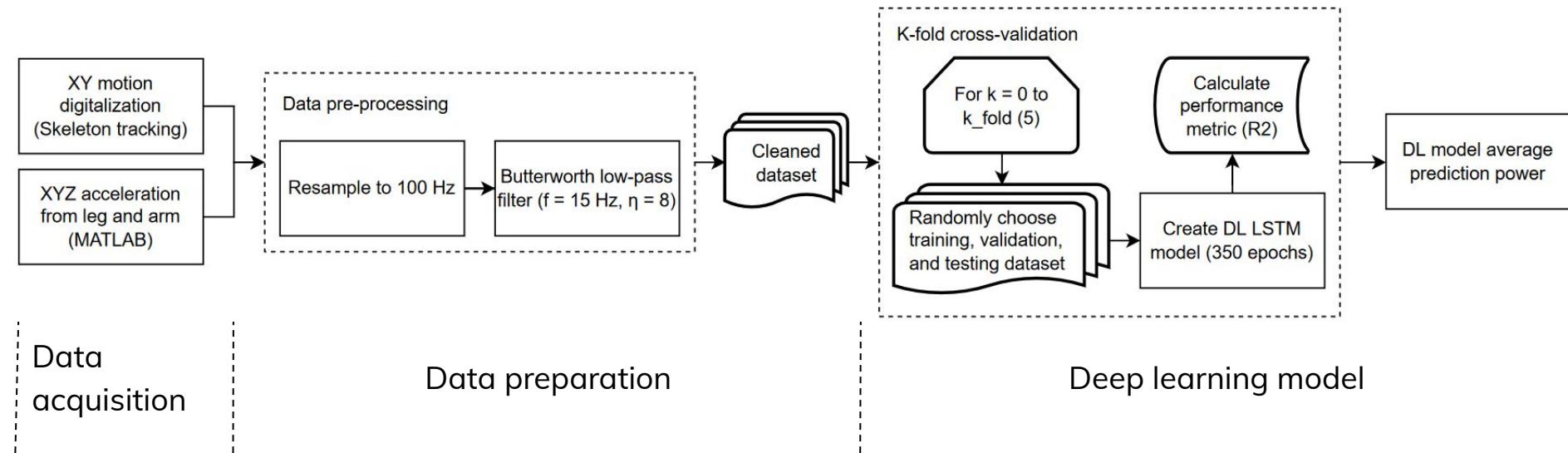
## Main objective

To create a **markerless biomechanical system** that predicts three-dimensional, human joint acceleration using video, by combining AI, CV and acceleration measurements during physical tasks.

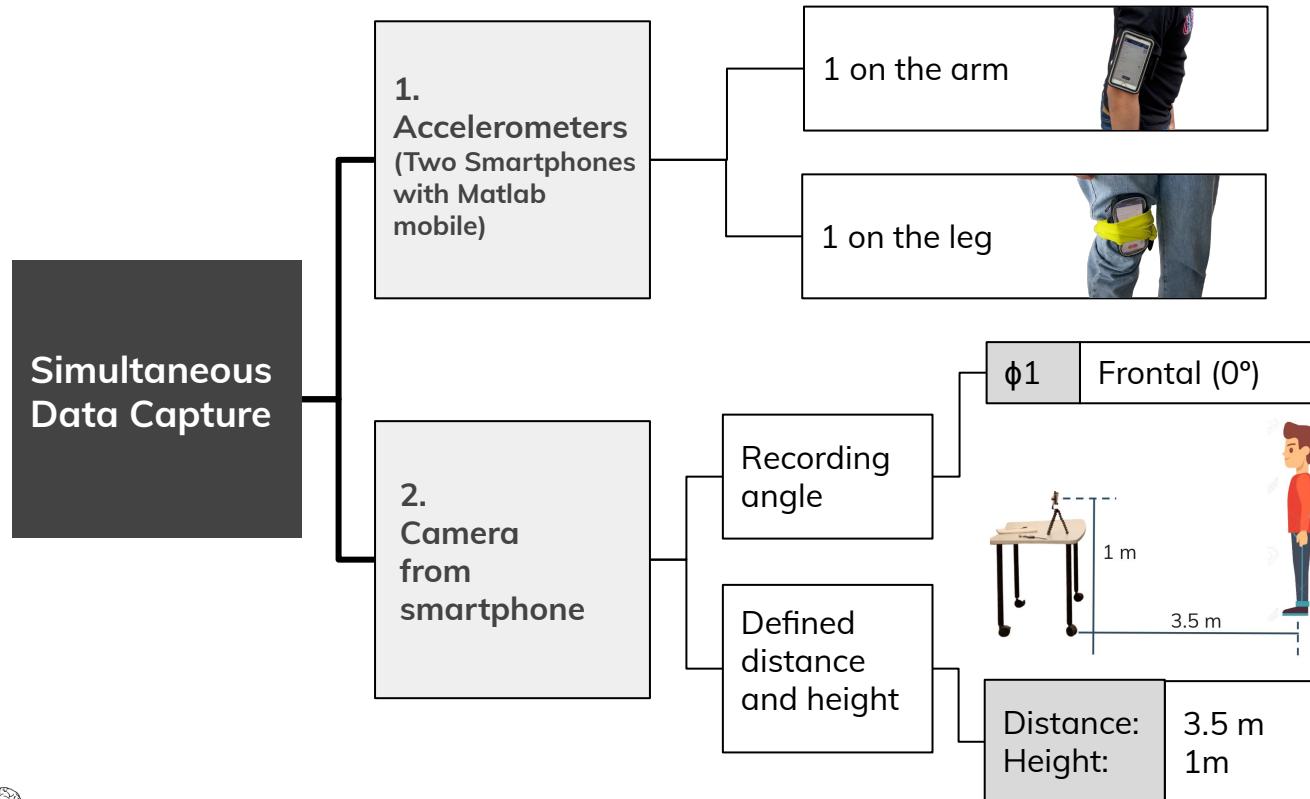
### Secondary objectives:

- 1) To create a **low cost** and **easy-to-implement** markerless motion tracking approach, using cell phones.
- 2) To obtain **motion data** and video from participants during specific physical tasks (walking, running, jumping).
- 3) To **train** an AI model using the **motion data and videos** obtained during experiments, that are able to **predict joint acceleration** from videos.
- 4) To evaluate different **methods** and propose the **best approach** for video-based, markerless estimation of joint acceleration.

# Methodology



# Experimental Protocol





**1.**  
**Accelerometers**  
(Two Smartphones  
with Matlab  
mobile)

1 on the arm



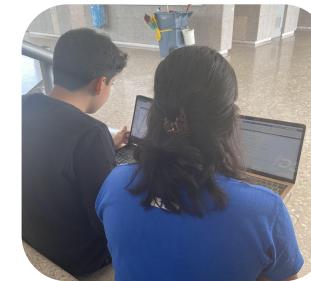
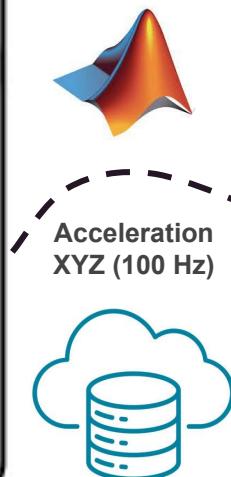
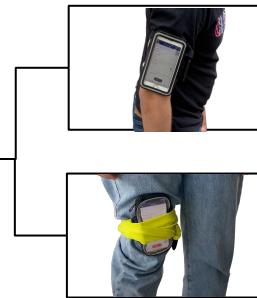
1 on the leg



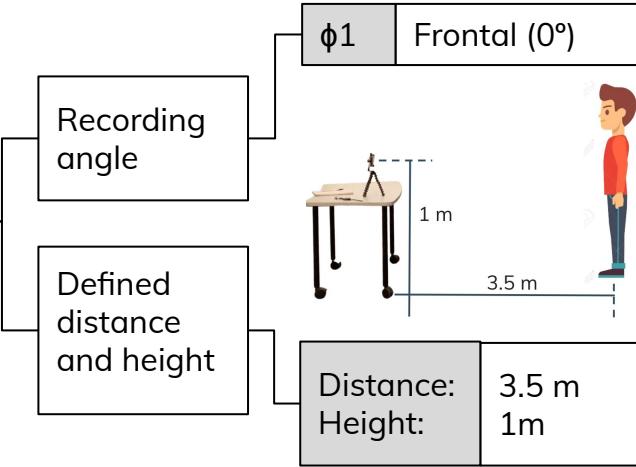


# Real-time data acquisition through Matlab

1.  
Accelerometers  
(Two Smartphones  
with Matlab  
mobile)



## 2. Camera from smartphone





126 datasets

- 2D Video
- Arm Acceleration
- Leg Acceleration

14 subjects  
18-23 years old

**Movement 1 (M1)**



Walk - 6m

**Movement 2 (M2)**



Run - 6m

**Movement 3 (M3)**



Jump

R1

R2

R3

R1

R2

R3

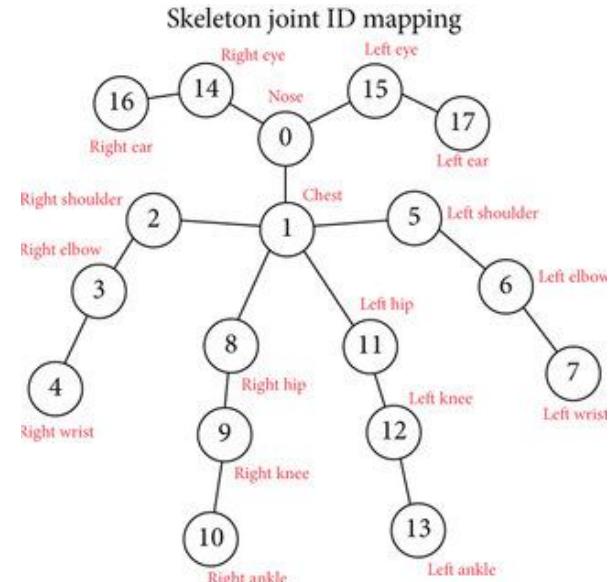
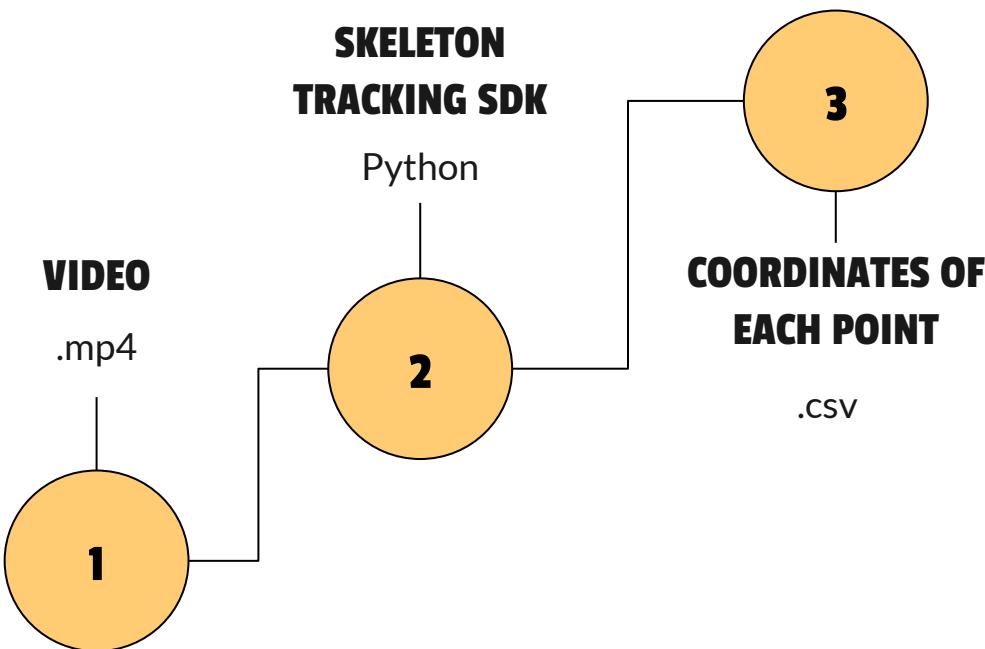
R1

R2

R3



# Automatic digitization of human movement



A photograph of a modern building's entrance. The entrance features four doors: two orange doors on the left and right, and two grey doors in the center. Above the central doors is a large glass window. The building has a dark grey facade and a polished floor. A white pillar is visible on the left. The background shows some greenery and a blue sky.

11/5/22 17:44:07.368  
200 Calle Montevideo  
- Alta Vista  
Monterrey  
Nuevo León

# Acceleration data preprocessing

Butterworth low-pass filter of order 8th, cutoff frequency of 15 Hz

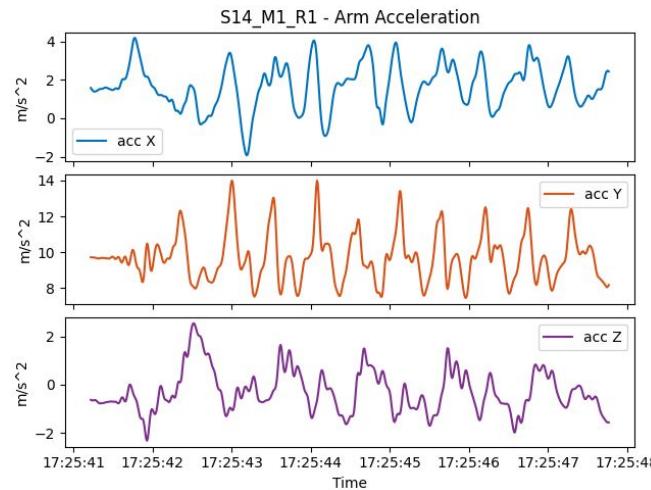


Fig. 1. Pre-Processed Arm Acceleration data corresponding to S14 M1 R1

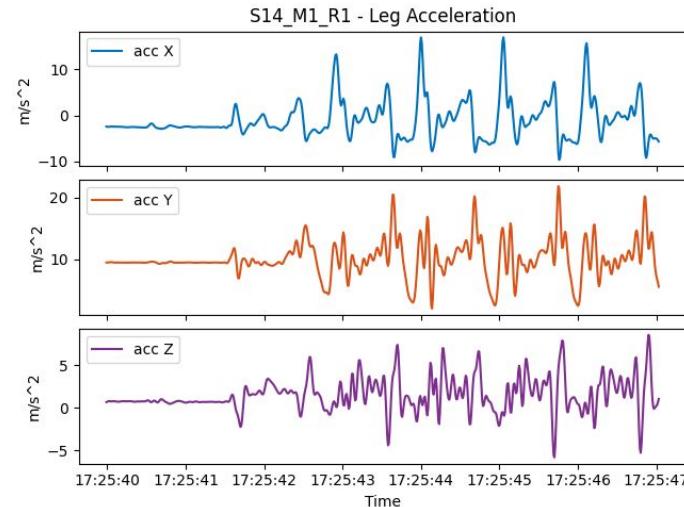


Fig. 2. Pre-Processed Leg Acceleration data corresponding to S14 M1 R1

## Position data preprocessing

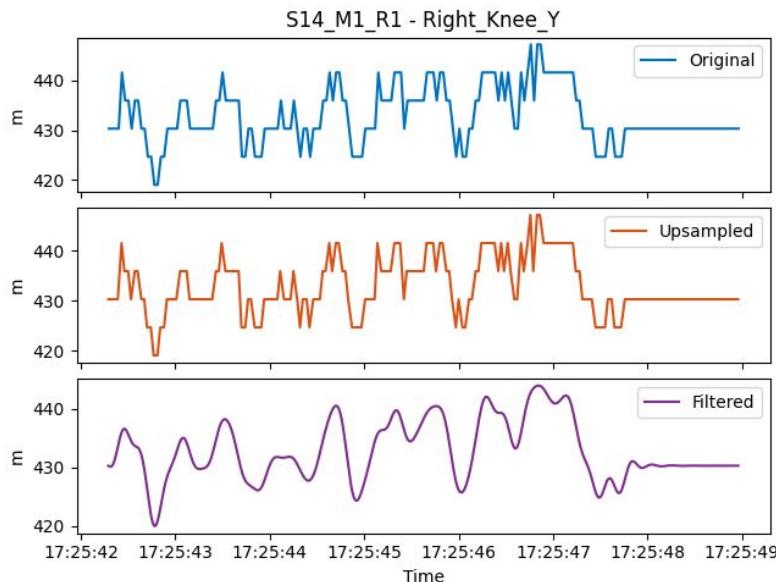


Fig. 3. Example of preprocessed key point signal of Right Knee (Y) corresponding to S14 M1 R1.

1. Delete invalid data
2. Resample to 100Hz
3. Butterworth low-pass filter of order 8th and cutoff frequency of 15 Hz

# Results

## Model training

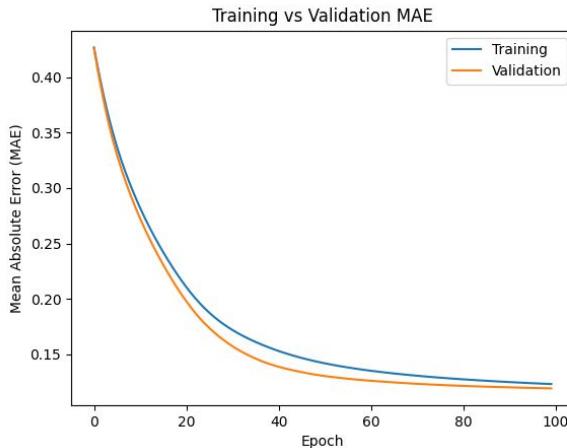


Fig. 4. Training and validation graphs of the loss function (MAE)

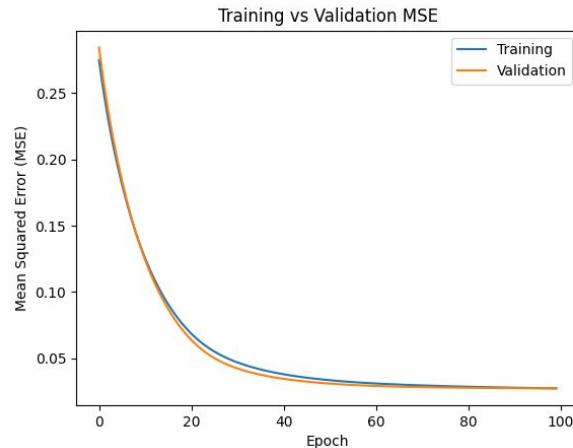


Fig. 5. Training and validation graphs of the loss function (MSE)

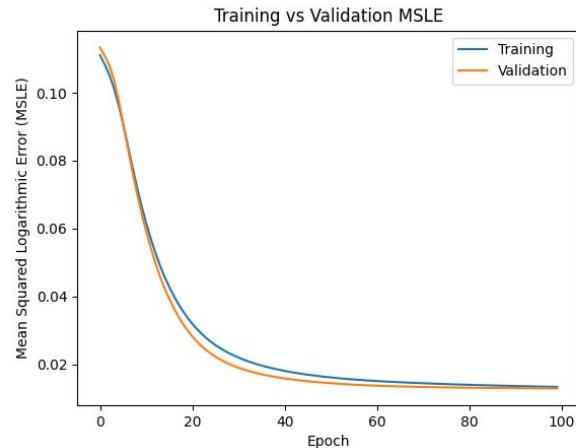


Fig. 6. Training and validation graphs of the loss function (MSLE)



# Deep Learning Model

TABLE I. RNN MODEL HYPER-PARAMETERS

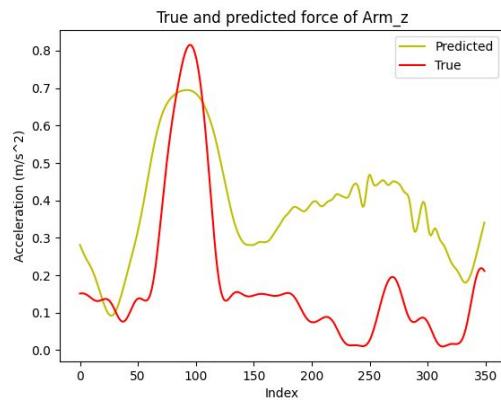
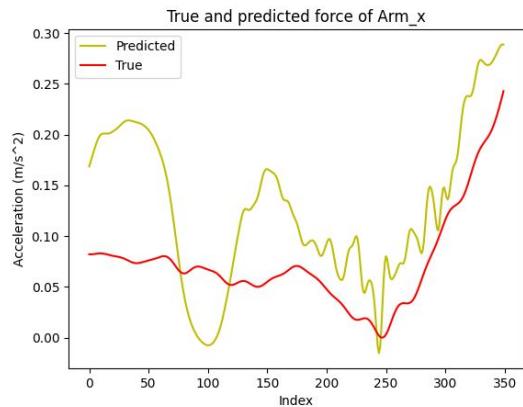
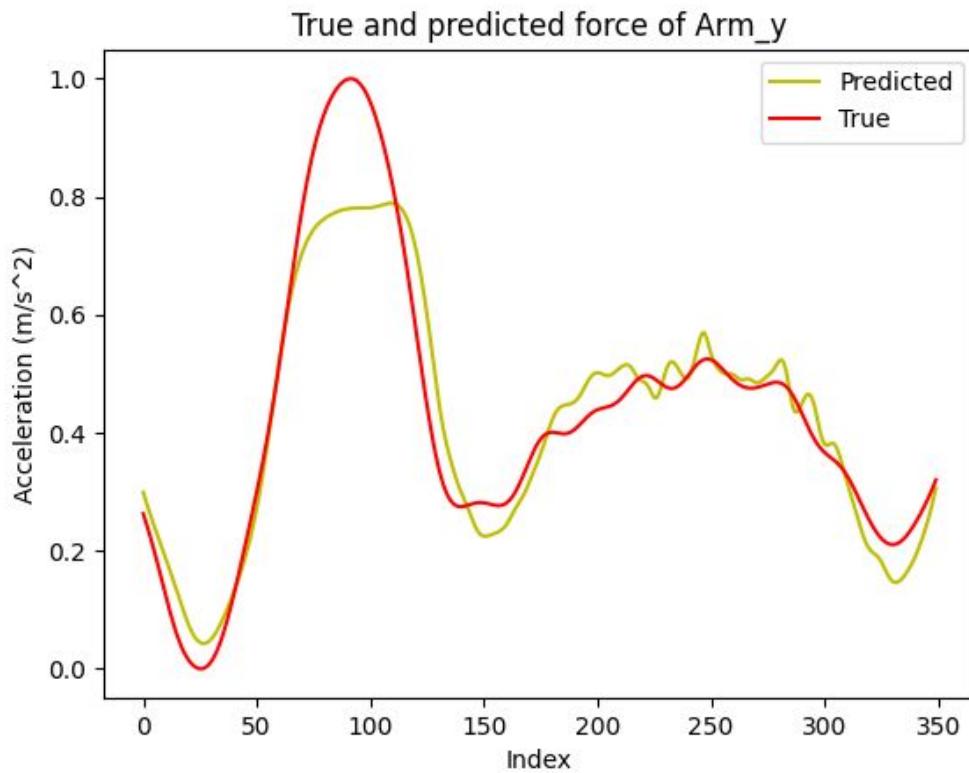
<b>Number of Epochs</b>	350
<b>Batch size</b>	128
<b>Sequence size</b>	10
<b>Layers</b>	LSTM (16), Dense (6)
<b>Loss function</b>	Mean Absolute Error (MAE)

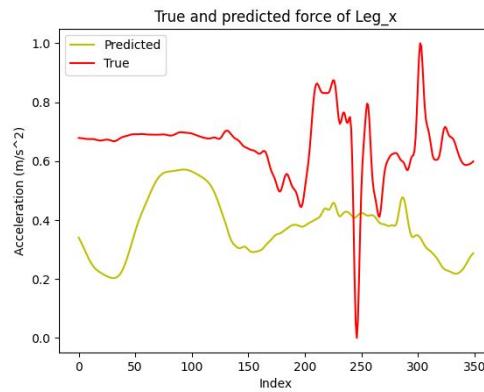
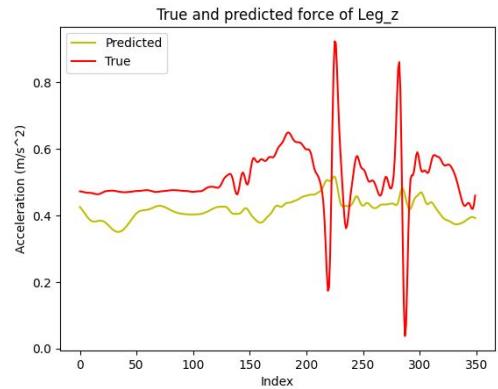
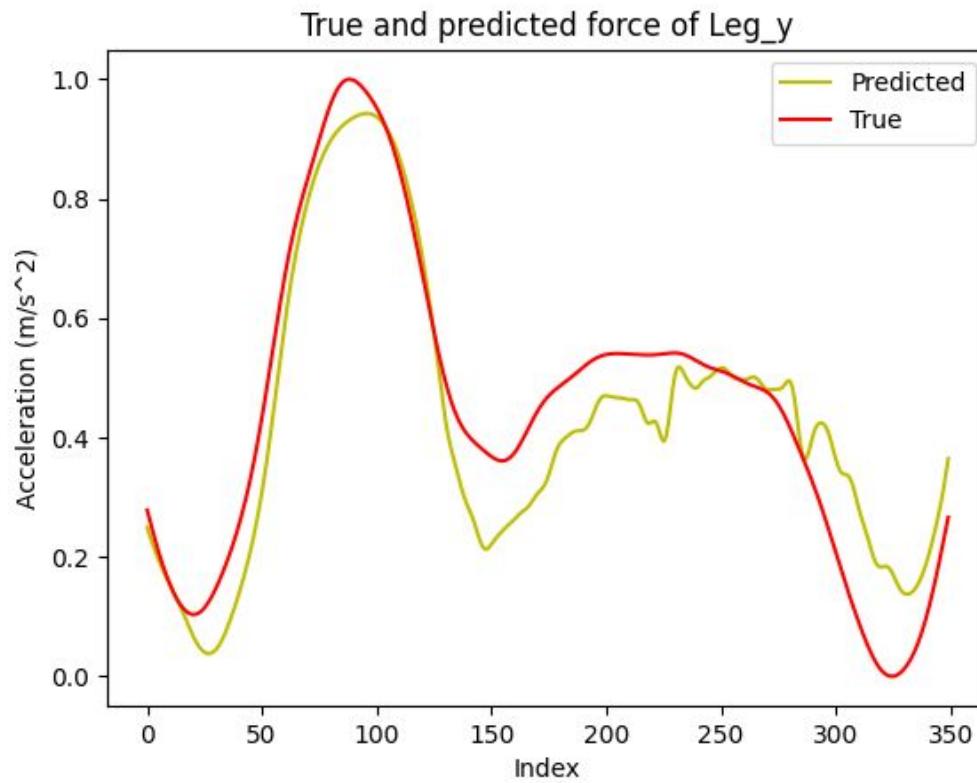


## Model Performance

TABLE II. COEFFICIENT OF DETERMINATION (R2) ON PREDICTIONS

DataSet	Leg			Arm		
	acc Z	acc Y	acc X	acc Z	acc Y	acc X
Training	0.055	<b>0.603</b>	<b>0.681</b>	0.168	0.573	0.553
Validation	-0.095	0.428	0.574	-0.046	0.447	0.399
Testing	-0.348	<b>0.527</b>	<b>0.533</b>	-0.248	0.521	0.369







## Conclusions

The study of certain movements during rehabilitation or sports training of patients can help **improve** sports performance and **prevent** injuries.

The model presented an **optimum** precision on its prediction, showing resembling behavior between the prediction and the real data acquisition with a maximum value of R<sup>2</sup> equal to **0.533**.

To improve the proposed model, future work will include more sensors into the setup to increase the number of degrees of freedom from which the model can learn, and therefore, increasing the chance to improve the accuracy of the model.

A perspective of this work, which is related to the long- term goal of the project is the development of an interconnected portable version of the proposed system, such that the joint acceleration estimations are performed in real- time.



Tecnológico de Monterrey  
Escuela de Ingeniería y Ciencias



# Detección del interés en ingeniería en niños mediante un sistema inteligente de señales biométricas

## Entrega de Resultados

Aimé Judith Aguilar Herrera  
Diego Mauricio Botín Sanabria  
Esther Aimeé Delgado Jiménez  
Gustavo Olivas Martínez  
Juan Carlos Ocampo Alvarado  
Luis Fernando Acosta Soto  
Milton Osiel Candela Leal  
Dra. Myriam Alanis Espinosa

Monterrey, N.L.

01 de Septiembre del 2021

# Equipo



**Dra. Myriam**

Investigadora  
principal



**Gustavo**

Ingeniería  
Mecatrónica



**Diego**

Ingeniería  
Mecatrónica



**Luis**

Ingeniería  
Biomédica



**Juan Carlos**

Psicología  
Clínica



**Milton**

Ingeniería  
Biomédica



**Esther Aimeé**

Ingeniería  
Biomédica



**Aimé Judith**

Ingeniería  
Biomédica

# Cronología de objetivos

## Diseño Experimental y set-up

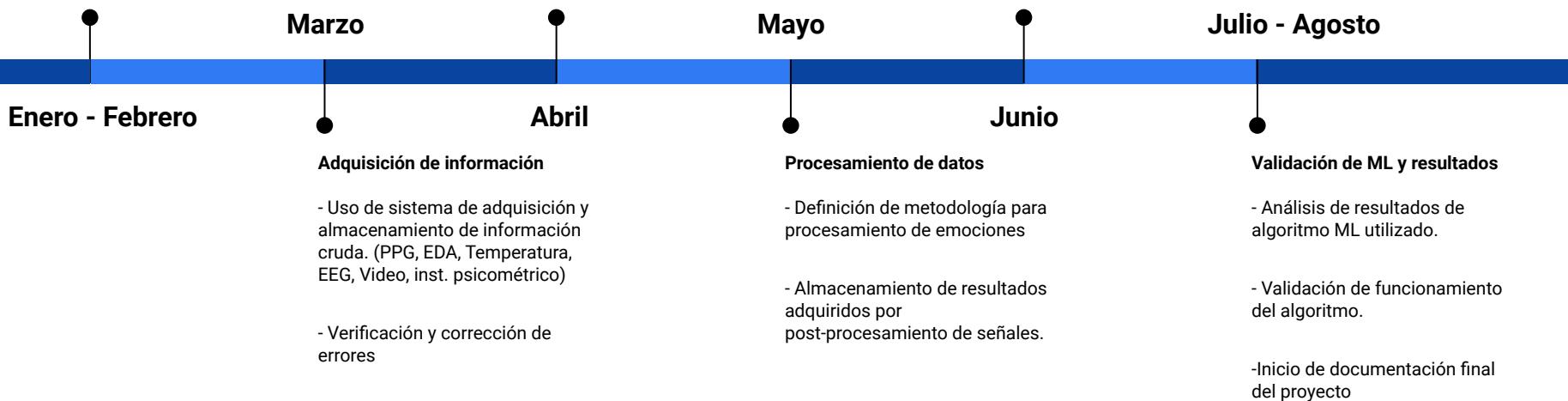
- Diseño y creación de sistema de adquisición
- Diseño de prueba psicométrica

## Procesamiento de datos

- Definición de metodología para procesamiento para datos PPG, EEG, EDA y psicometría.

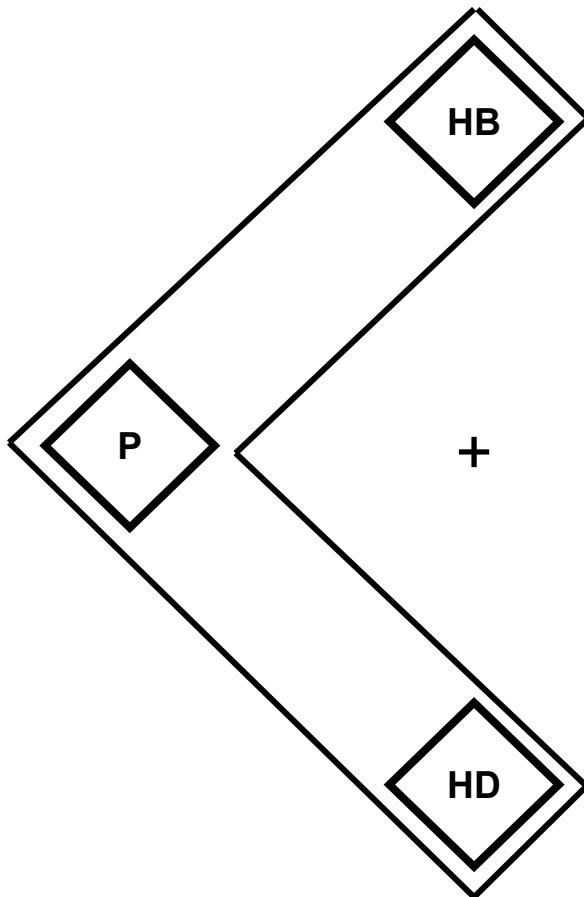
## Machine Learning

- Análisis exploratorio de datos y definición de algoritmo usado para procesamiento de resultados.

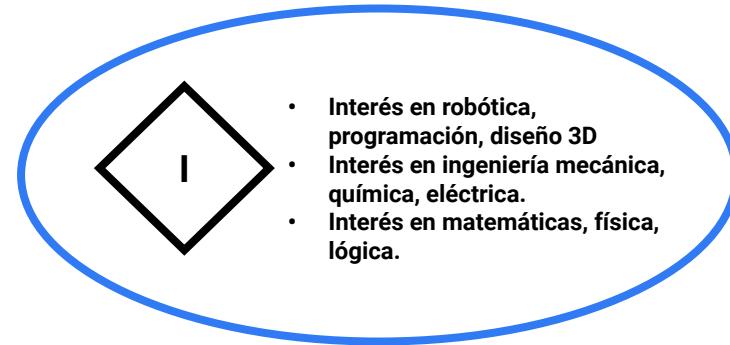


# Psicometría

- Lúdico
- Productivo
- Social
- Servicial
- Investigativo
- Emprendedor
- Líder



- Creatividad
- Organización
- Manualidad
- Gestión
- Prosocialidad
- Pensamiento crítico
- Inteligencia interpersonal



- Interés en robótica, programación, diseño 3D
- Interés en ingeniería mecánica, química, eléctrica.
- Interés en matemáticas, física, lógica.

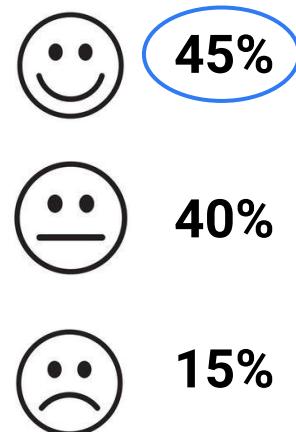
- Razonamiento numérico, abstracto, espacial
- Electricidad, mecánica, electrónica
- Presaberes matemáticos, físicos, mecánicos, lógicos

**AEQ-PA**

# Cuestionario de emociones para situaciones de aprendizaje

**Ocho emociones:** disfrute, esperanza, orgullo, ira, ansiedad, vergüenza, desesperación y aburrimiento

1. Pensar en la clase de hoy me pone nervioso
2. No estoy emocionado por la clase de hoy
3. No me irá bien en la clase de hoy



# Antes del módulo

Participante	Programación	Robótica	Diseño 3D*
Arturo	3.4	3.3	3.6
Emiliano	3.1	3.6	3.8
Marcelo	3.3	2.6	3.1
Mateo	3.1	3.1	3.4
Joaquín	2.5	3	3
Jezael	3.3	2.9	2.7
Evelyn	3.3	3.2	3.2
Israel	3	3.4	3.2
Alejandro	2.6	3.1	3.1
Patricio	2.9	3.2	2.9
Jorge	2.7	2.5	3.1
Ernesto	2.9	3.8	3.5
Sofía	2.9	3	3.4
Promedio	3.04	3.17	3.23

# Después del módulo

Participante	Programación	Robótica	Diseño 3D*
Arturo	3.5	3.9	3.5
Emiliano	3.8	3.8	3.5
Marcelo	3.8	3.8	3.7
Mateo	3	3.6	3.2
Joaquín	2.4	2.5	2.4
Jezael	2.4	2.6	2.6
Evelyn	3.3	3.5	3.1
Israel	3.8	3.5	3
Alejandro	3.2	3.1	2.8
Patricio	2.8	4	3
Jorge	3.3	3.8	3.5
Ernesto	3.2	3.5	3.1
Sofía	3.4	3.5	3.1
Promedio	3.22	3.46	3.11

# Diferencia por grupos

## Antes del módulo

	Primaria (6-11 años)	Secundaria (12-14 años)
Programación	3.14	2.83
Robótica	3.21	3.16
Diseño 3D*	3.26	3.20

## Después del módulo

	Primaria (6-11 años)	Secundaria (12-14 años)
Programación	3.28	3.17
Robótica	3.57	3.39
Diseño 3D*	3.08	3.14

# Procesamiento de datos

# Sistema de adquisición

- Scripts diseñados con Python con el objetivo de operar una adquisición simultánea entre los dispositivos **LiveAmp de Brain Products (EEG)**, banda inteligente **E4 de Empatica (PPG, EDA)** y una **cámara stereo d435i** (emociones) por Intel.
  - Documentación de código disponible [aquí](#).
  - Manual de uso e instalación disponible [aquí](#).
  - Código disponible [aquí](#).

# Análisis de datos

- Uso de Python para procesar datos de la banda inteligente (PPG, EDA) y de video (emociones).
  - Documentación disponible [aquí](#).
  - Código disponible [aquí](#).

# Análisis de datos

- Uso de Python para preprocesamiento de las señales de EEG.
  - Formateo de datos en un arreglo compatible con Matlab
  - Filtrado de la banda de interés ( $1 \text{ hz} < f < 100 \text{ hz}$ )
  - Documentación disponible [aquí](#).
  - Código disponible [aquí](#).
- Uso de Matlab para procesamiento de señales
  - Filtrado en bandas de interés (Alpha, Beta, Gamma, Delta, Theta)
  - Cálculo de potencias de las bandas
  - Extracción de la media móvil en el tiempo
  - Cálculo de factores de interés (compromiso, carga cognitiva, fatiga mental)
  - Documentación disponible [aquí](#).
  - Código disponible [aquí](#) y [aquí](#).

# Machine Learning

# VARIABLES OBJETIVO

Calificación de Machine Care por cada clase tomada (Robótica, Programación, Diseño 3D).

ROBÓTICA	PROGRAMACIÓN	DISEÑO 3D
3.5	3.75	5

1	Malo
2	Insuficiente
3	Regular
4	Bueno
5	Excelente

Cambio en el interés en materias de ingeniería por cada prueba psicométrica.

preprog	posprog	predis	posdis	prerob	posrob
3.4	3.5	3.6	3.5	3.3	3.9
3.1	3.8	3.8	3.5	3.6	3.8
3.3	3.8	3.1	3.7	3.4	3.8
3.1	3	3.4	3.2	3.1	3.6
2.5	2.4	3.0	2.4	3	2.5
3.3	2.4	2.7	2.6	2.9	2.6
3.3	3.3	3.2	3.1	3.2	3.5
3	3.8	3.2	3	3.4	3.5
2.6	3.2	3.1	2.8	3.1	3.1
2.9	2.8	2.9	3	3.2	4
2.7	3.3	3.1	3.5	2.5	3.8
2.9	3.2	3.5	3.1	3.8	3.5
2.9	3.4	3.4	3.1	3	3.5

# Objetivo

- El código para normalizar los datos de los dispositivos biométricos, y crear un conjunto de datos con los valores objetivo [aquí](#).



Machine  
Learning



Calificación

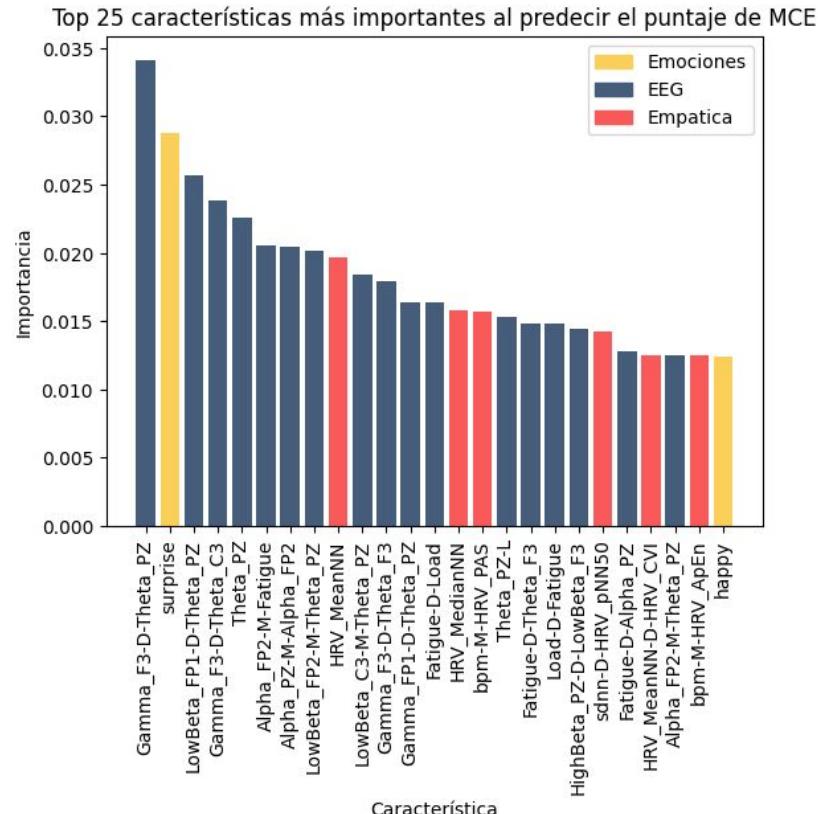


Interés

# Importancia de características (calificación MCE)

Se utilizó un **algoritmo de árboles aleatorios** para obtener la importancia de las características (más es mejor).

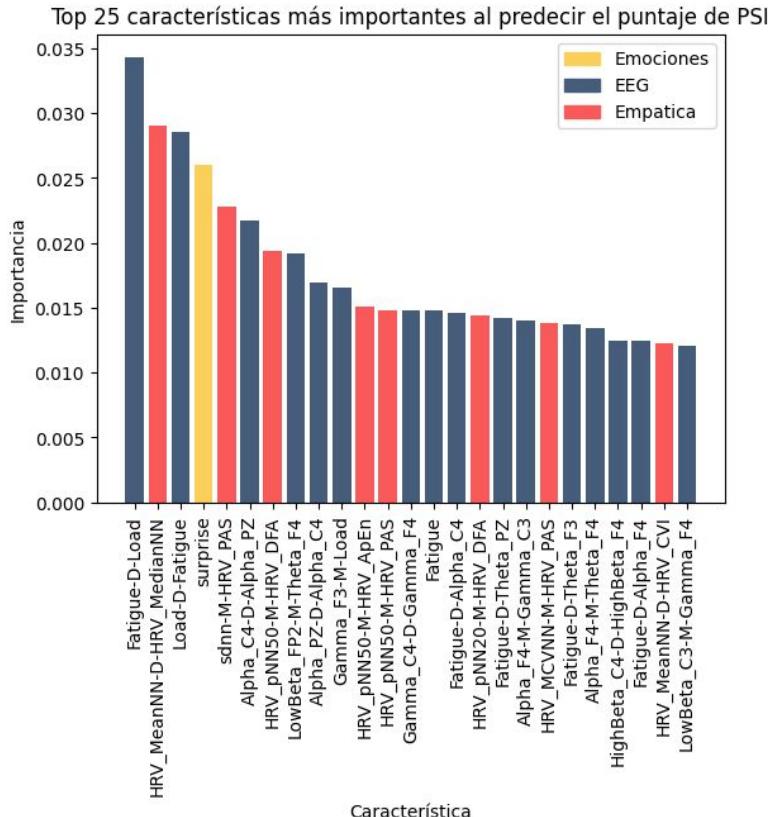
- La mayoría de las características predictoras corresponden al electroencefalograma (EEG) y las emociones (sorpresa), con colores azul y amarillo en el diagrama.
- Los canales significativos empiezan con F (F3, FP1, FP2), correspondientes al lóbulo frontal relacionado con la inteligencia, la cual es reforzada durante los cursos.



# Importancia de características (prueba psicométrica)

Se utilizó un **algoritmo de árboles aleatorios** para obtener la importancia de las características (más es mejor).

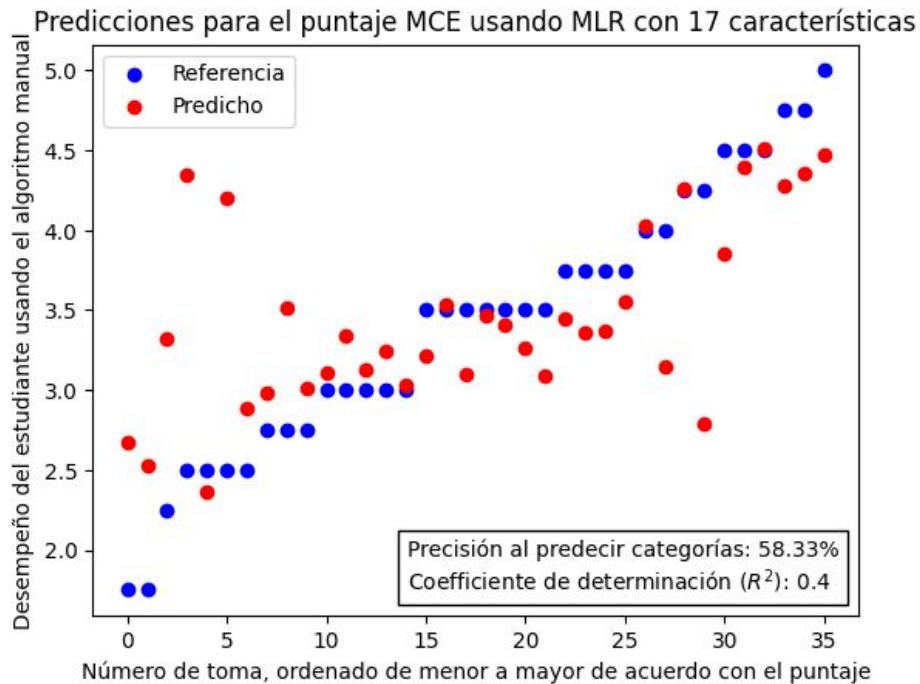
- Fatiga, carga mental y variabilidad del ritmo cardíaco, son características importantes relacionadas con el interés en materias de ingeniería.
- Dichas características importantes son variadas: EEG; Empatica, además de la probabilidad de sorpresa.
- Sorpresa de nuevo se debe a que los estudiantes son niños, y así es como comúnmente expresan lo aprendido.



# Resultados (calificación MCE)

Con las 17 mejores características, se creó un modelo **Regresión Lineal Múltiple (MLR)**, por cada clase de cada niño y se validó con el resto.

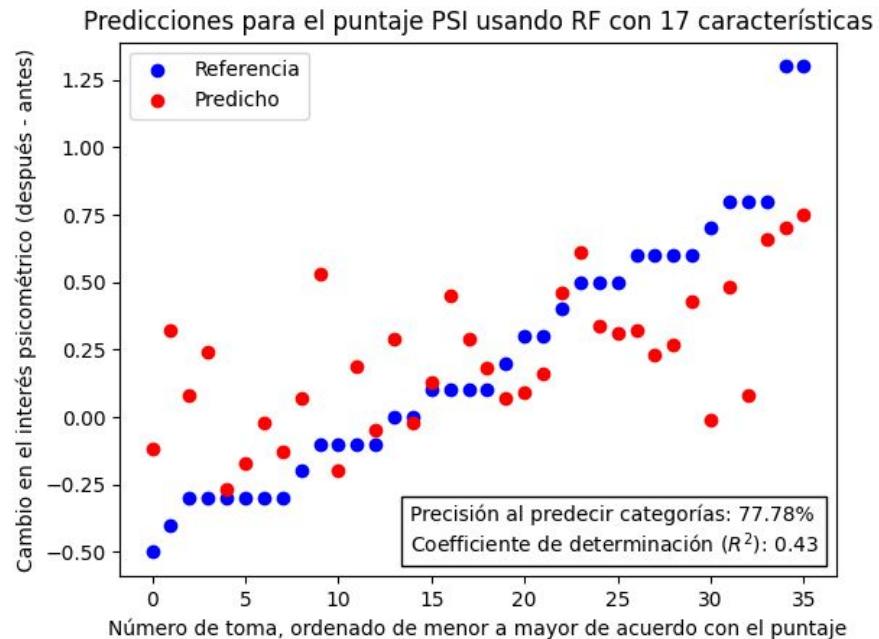
- Hay una tendencia de predicción, pero falla en valores extremos por escasez de datos por categoría (categoría *Insuficiente*).
- Precisión del 58.33% al detectar la categoría con base en la calificación, considerando que se utilizaron todos los niños y no se removieron valores atípicos.



# Resultados (prueba psicométrica)

Con las 17 mejores características, se creó un modelo **Árboles Aleatorios (RF)** en este caso, por cada clase de cada niño y se validó con el resto.

- Menos margen de error en las predicciones, pero el coeficiente de determinación sigue siendo bajo al predecir comportamiento.
- Se detecta con precisión del 77.78% si el cambio en el interés será positivo o negativo, clave para intervenciones tempranas.



# Conclusiones

- Se logró obtener el diseño e implementación de un sistema de **detección de talento + pasión** basado en señales fisiológicas. El algoritmo puede ser capaz de realizar predicciones para nuevos niños.
  - Precisión del **58%** para la **calificación**. (Talento)
  - Precisión del **78%** para el **cambio en el interés**. (Pasión)
- Se propuso una **reestructuración** en la manera en que se detecta el **interés** y las **habilidades** blandas/duras (psicometría).
- Generación de **reportes para cada estudiante** resumiendo visualmente el desempeño para cada área de la ingeniería (Diseño 3D, Robótica y Programación)

# Digital Twin Office

# Propuesta para predicción de acciones



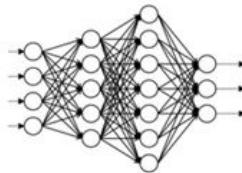
## Actual

- Posición con keypoints XYZ
- Ángulos con ciertos keypoints (literatura)



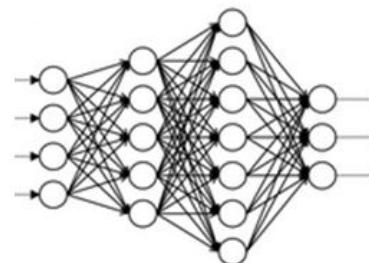
## Possible

- Aceleración XYZ en pierna y brazo predicha con RNN



## Procesamiento

RNN clasificación multi clase



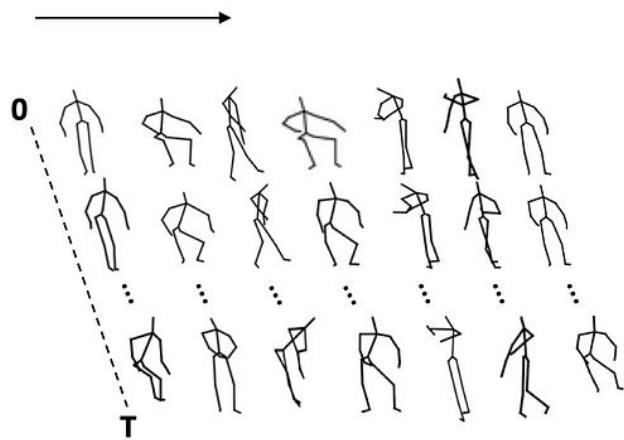
## Predicción

De acciones: Saltar, correr, caminar, estar quieto



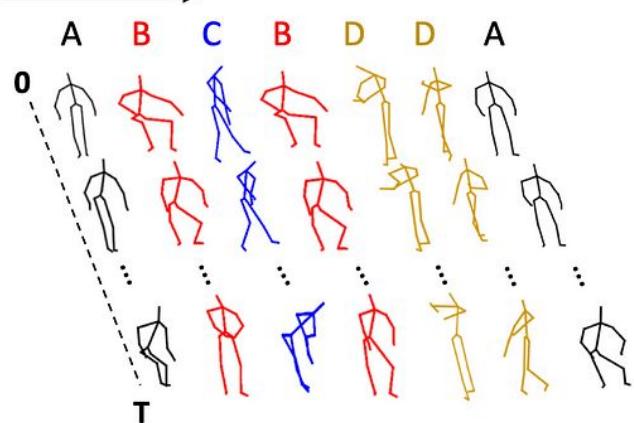
# Human action recognition (HAR)

Actions



?

Actions & Classes



# Metodología

