2022 IUCRC BRAIN Annual Meeting

Digital Twin modelling for Human Biomechanics and Office Spaces

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Focus, Need, and Industrial Relevance

- The project focuses on movement tracking through video analysis to estimate acting forces on the body, while also predicting the action done by the subject.
- Direct applications include sports to measure athletes' performance in real-time, and office to monitor actions.

Project Objectives

To create a human, biomechanical DT that tracks a person's movement using a marker-less approach via a CV algorithm, further using DL models to not only predict limbs XYZ acceleration (arm, leg), but also the action that is being performed (walk, run, jump).

Research Methods

- Video ($f_s = 30\ Hz$) motion digitization Skeletal Tracking SDK by Cubemos
- Acceleration collected via smartphones using MATLAB Mobile ($f_s = 100\ Hz$)
- DL RNN multi-output model creation using Tensorflow and Keras

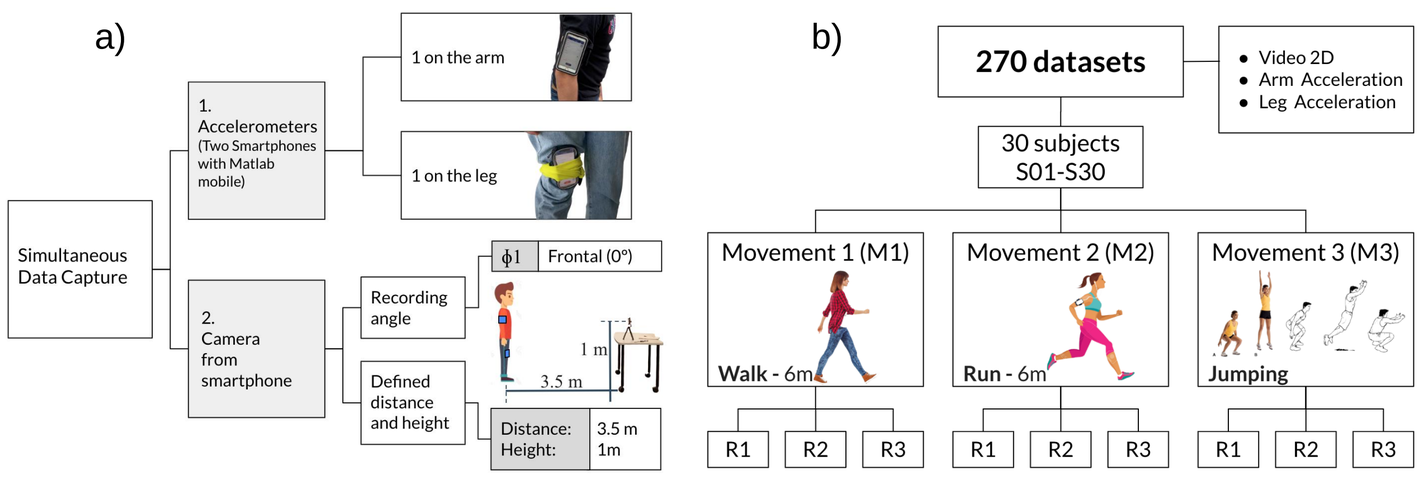


Figure 1. Data recollection methodology: a) Video and accelerometer, b) Data division and kinematic actions

Project Outline

Using a 2D camera, and a CV algorithm, to track a human's movement via 28 keypoints. These were used as input features on two DL one-layered LSTM regression models: To predict XYZ acceleration and action.

On the other hand, office digitization and 3D reconstruction on client's installations was done using Puck Hi-Res Velodyne® LiDAR on a moving shelf as shown in Figure 2.

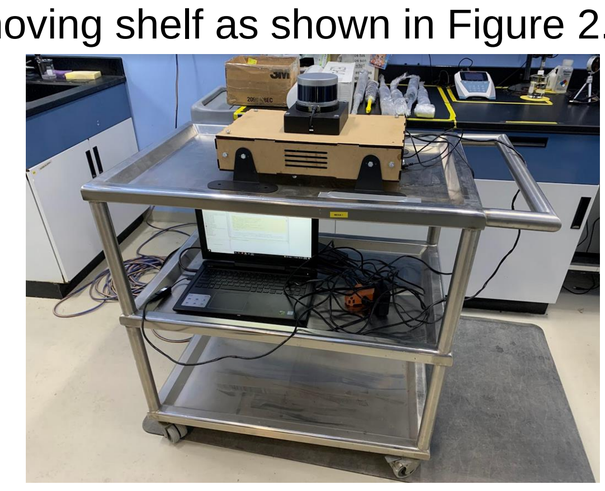


Figure 2. Setup configuration consisting on a Puck Hi-Res and Laptop

Office digitization result via VeloView and point cloud recordings is shown in Figure 3.

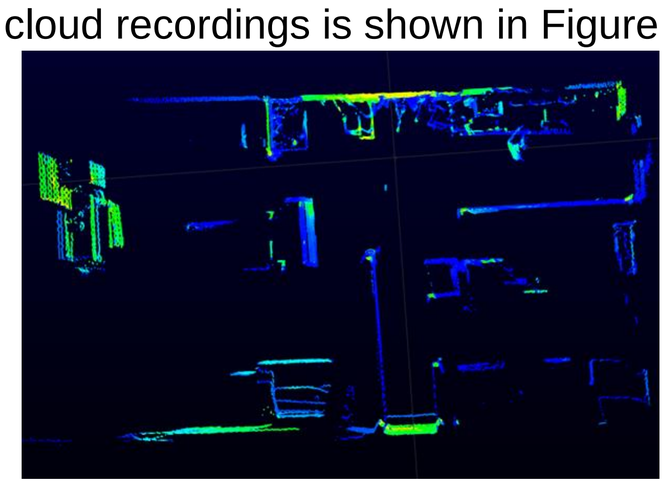


Figure 3. Xperto Integral Systems' laboratory digitization

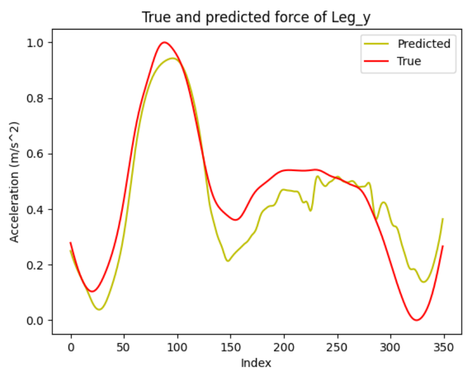
Project Goal

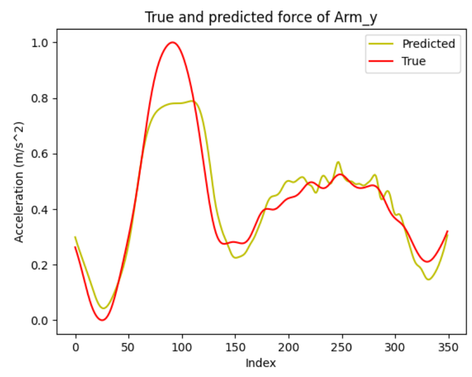
- To create an accessible, easy-to-use real-time marker-less DT system to model human biomechanics and their actions in office spaces.
- Focus on martial arts (Taekwondo) to asses correct execution (force and form).

Project Results

XYZ, arm and leg, acceleration prediction on LSTM $R^2 = (0.4534, 0.4594, 0.3148)$, poor performance Arm XZ, when removed, average $R^2 = (0.6842, 0.6806, 0.5376)$. Figure 4 shows reference and predictions.

a)



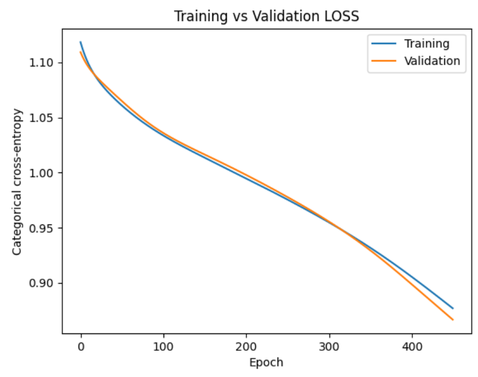


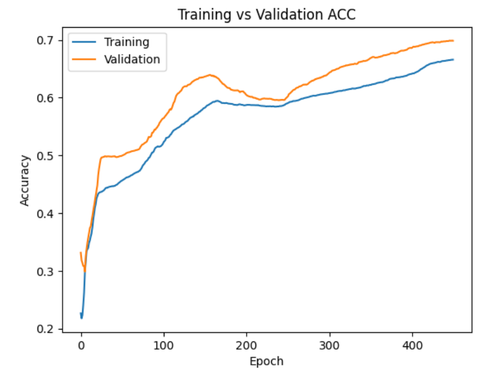
b)

Figure 4. Scaled acceleration: Reference (red line), predicted (yellow line). Test dataset R^2 a) 0.5355 b) 0.4713

HAR model using LSTM with the same 28 keypoints features extracted from the Skeletal Tracking SDK, in Figure 5 close to 70% accuracy using 5 sequences of 10 ms (50 ms of data to make a prediction).

a)



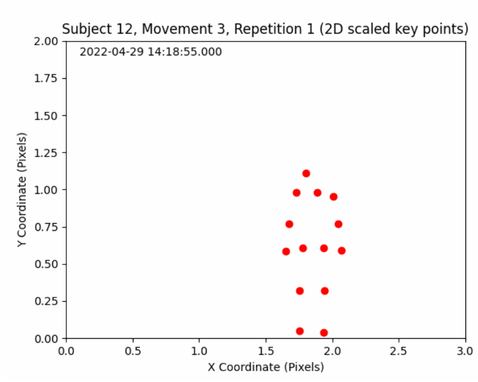


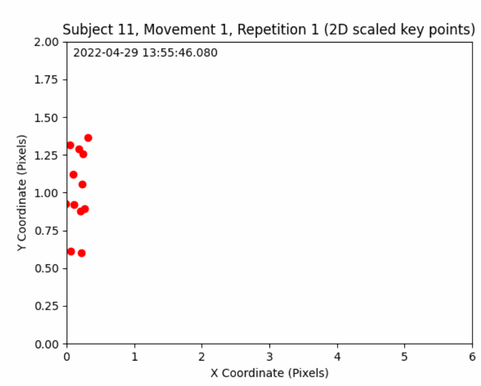
b)

Figure 5. Model's a) categorical cross-entropy loss and b) accuracy for epochs (epochs = 450), with acc ≈ 0.7

Considering 50 samples (5 s), in Figure 6, HAR model successfully identified Walk and Jump actions on real-time and average per video.

a)





b)

Figure 6. HAR in real time (5 s), with a final average prediction on the overall action done: a) Walk, b) Jump

Deliverables and Expected Impact

- A biomechanical database of 30 subjects of video and acceleration.
- Two DL models: One that predict limb XYZ acceleration and HAR.
- Platform focused as an individual sport assessing tool (Taekwondo).