INSTITUTE
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INFORMATION
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TECHNOLOGIES

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Assessment of task ergonomics with an upper limb wearable device

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Outline

- Introduction
- Objective
- Ergonomic assessment
- System
- Motion and muscular activity tracking
- Experiment
- Results
- Conclusion

Upper Limb Work-related Musculo Skeletal Disorders

Thousands of worker suffering from work related upper limb musculo skeletal disordes (ULWMSD). In Italy, in 2007 ULWMSD were the 41,6% of all the work-related pathologies.

- Wrist, elbow and shoulder are interested
- Unstructured workplaces
  - ➢ do no allow us to quantitatively measure the worker activities in situated environments
  - ➢ cannot be easily modified to reduce potential causes of ULWMSD

Objective

Develop a system for quantitative ergonomic assessment in unstructured environments

- Selection of an ergonomic assessment method
- Fully wearable capture device supporting
  - Motion tracking
  - Muscular activity tracking
  - Feature extraction for ergonomic assessment
  - **Quantitative ergonomic assessment**

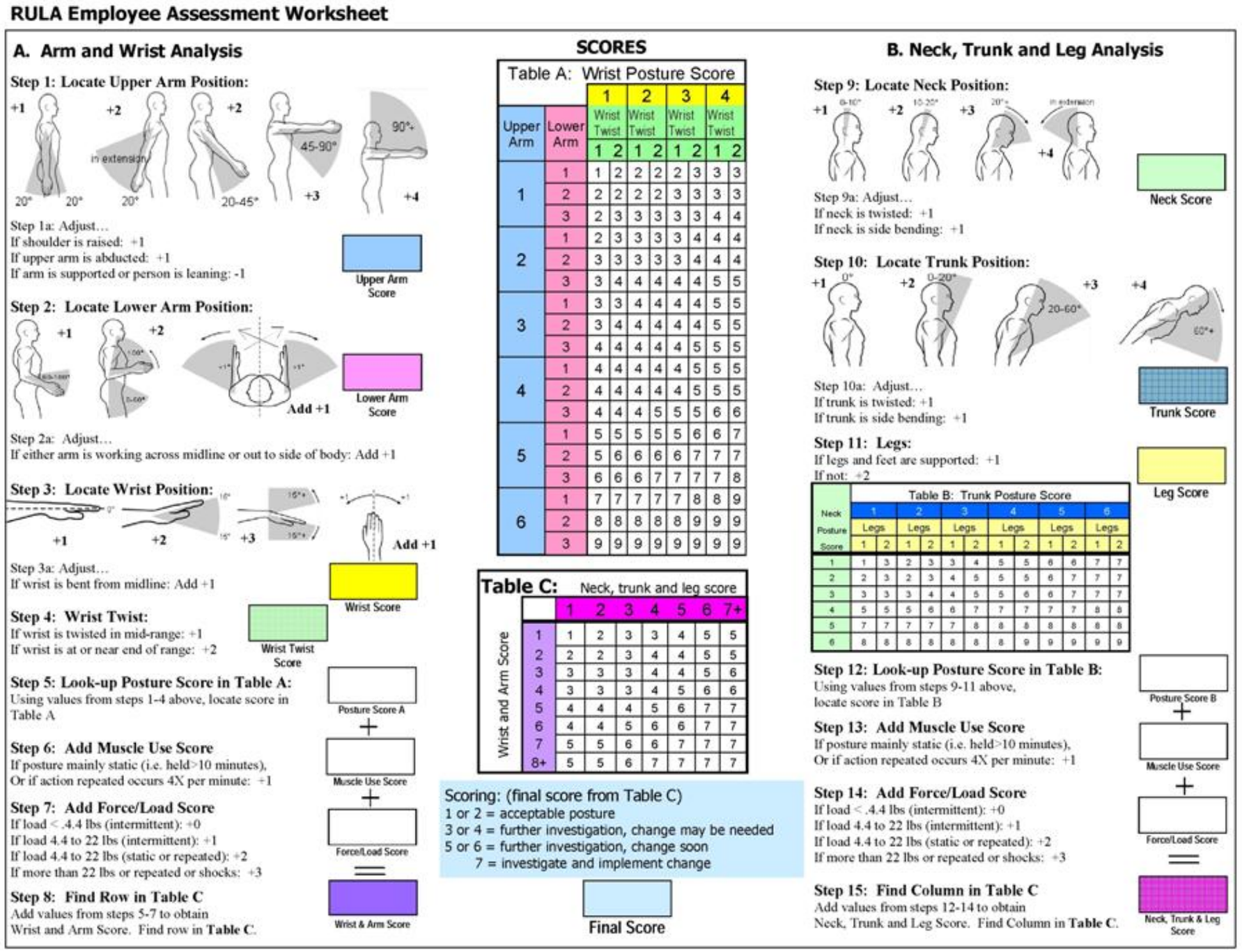
Ergonomic assessment

Several methods for ergonomic assessment cited by ISO 11228 and UNI-EN 1005 regulations

Method	Description	Output
RULA	Analysis of postures of different body segments; it also considers their frequency during a work shift	Quantitative
OCRA ckl	Semi-detailed method that considers, in a simplified way, the same risk factors as the OCRA index. Exposure level is classified in the three-zone system. Applicable also to multitask repetitive jobs.	Quantitative
HAL	Detailed method (for monotask handwork lasting almost 4 h per shift) mainly based on the analysis of frequency of actions (in relation to duty cycle) and of peak force; other main factors are generically considered.	Quantitative
NIOSH Lifting Index	Evaluation of the risks related to manual handling of load during lifting tasks	Quantitative
OWAS	Analysis of postures of different body segments; it also considers their frequency during a work shift	Quantitative

RULA

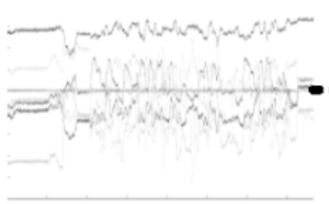
- Assessment Workflow composed of **joint angles** measurements, **force estimation** and **muscular activity triggers**.
- Selected as the easisest to implement among the ISO 11228 compliant



System Architecture

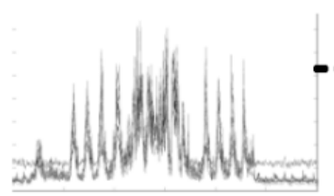
Online, wearable

IMU Signal



EMG Signal

EMG Features

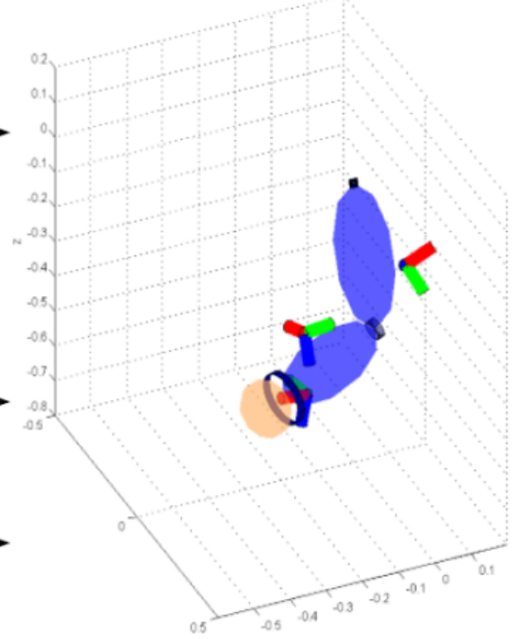


Offline

Motion Reconstruction

Activity Segmentation

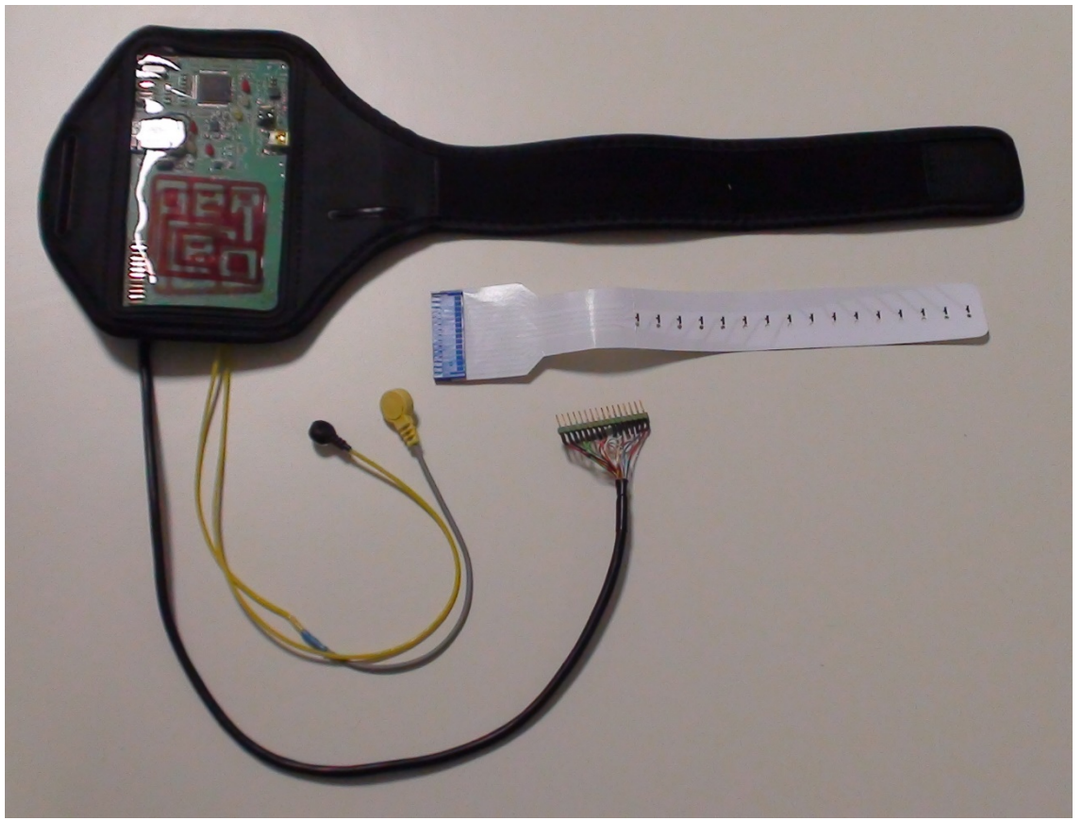
Visual Representation and RULA Score



Device

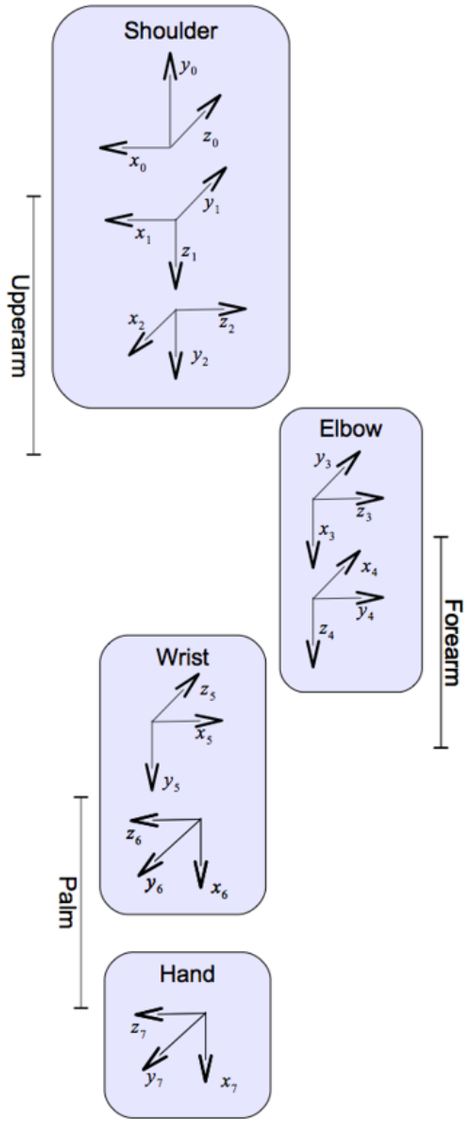
Fully werable board supporting:

- STM32F micro
- 4 Invensense 9150 IMUs:
  - ➢ 3 axes accelerometer
  - ➢ 3 axes gyroscope
  - ➢ 3 axes magnetometer
- 32 EMG channels
- Maximum sampling frequencies
  - ➢ IMUs @ 100 Hz
  - ➢ EMG @ 500 Hz
- On-board EMG filtering and feature calculation



Motion Tracking

Kinematic model of the human upper limbs

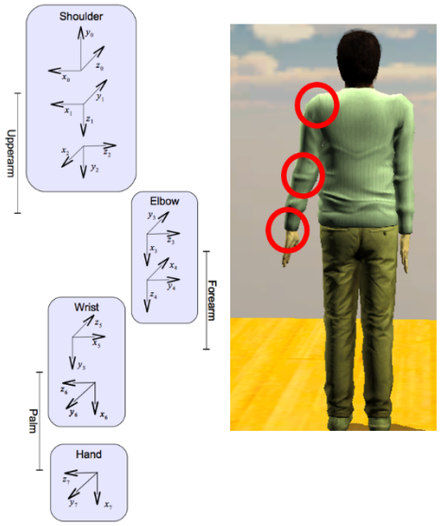


- 7 DoFs rigid bodies kinematic chain
  - Rooted in the chest
  - Shoulder abduction-adduction
  - Shoulder rotation
  - Shoulder flexion-extension
  - Elbow flexion-extension
  - Forearm pronation-supination
  - Wrist flexion - extension
  - Wrist abduction - adduction
- IMUs associated to s# frames
  - Rigid transformation from parent link to sensor frame

Motion Tracking

Unscented Kalman Filter for IMUs sensors fusion

Filter State



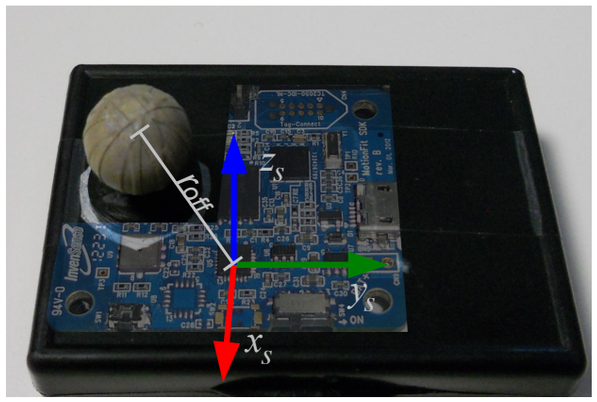
$$\Theta = \begin{bmatrix} \vartheta_1 \\ \dot{\vartheta}_1 \\ \ddot{\vartheta}_1 \\ \vdots \\ \ddot{\vartheta}_7 \end{bmatrix}$$

Process Model

$$\vartheta_i(k+1) = \vartheta_i(k) + T_s\dot{\vartheta}_i(k) + \frac{1}{2}T_s^2(\ddot{\vartheta}_i(k) + \nu_k)$$

$$\dot{\vartheta}_i(k+1) = \dot{\vartheta}_i(k) + T_s(\ddot{\vartheta}_i(k) + \nu_k)$$

$$\ddot{\vartheta}_i(k+1) = \ddot{\vartheta}_i(k) + \nu_k$$



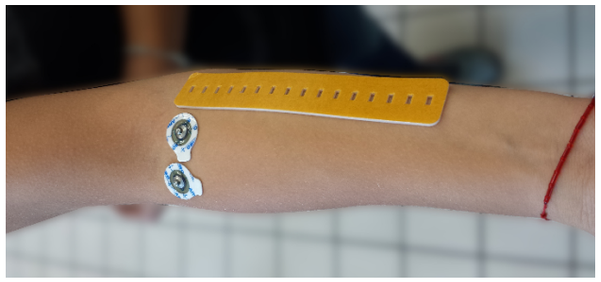
Measurements Model

$$\omega_s^s = R_p^s(\omega_p^p + \dot{\vartheta}_{p+1}z_0)$$

$$\ddot{x}_s^s = R_p^s\ddot{x}_p^p + S(\dot{\omega}_s^s)r_{p,s}^s + S(\omega_s^s)^2 r_{p,s}^s + R_0^s g^0$$

$$m_s^s = R_0^s m^0$$

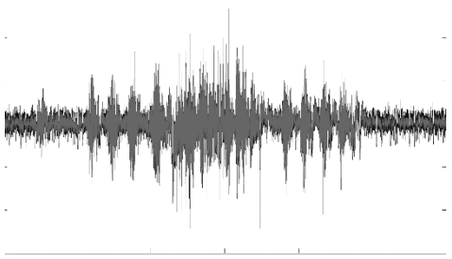
Muscular activation

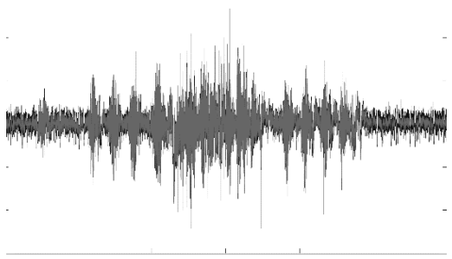


8 Channels

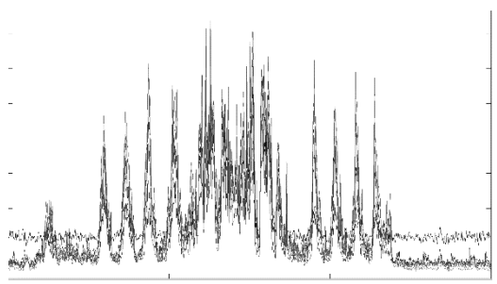
EMG

Raw Signals → Bandpass Filter [20 - 200] Hz → RMS → Windows 128ms





MVC



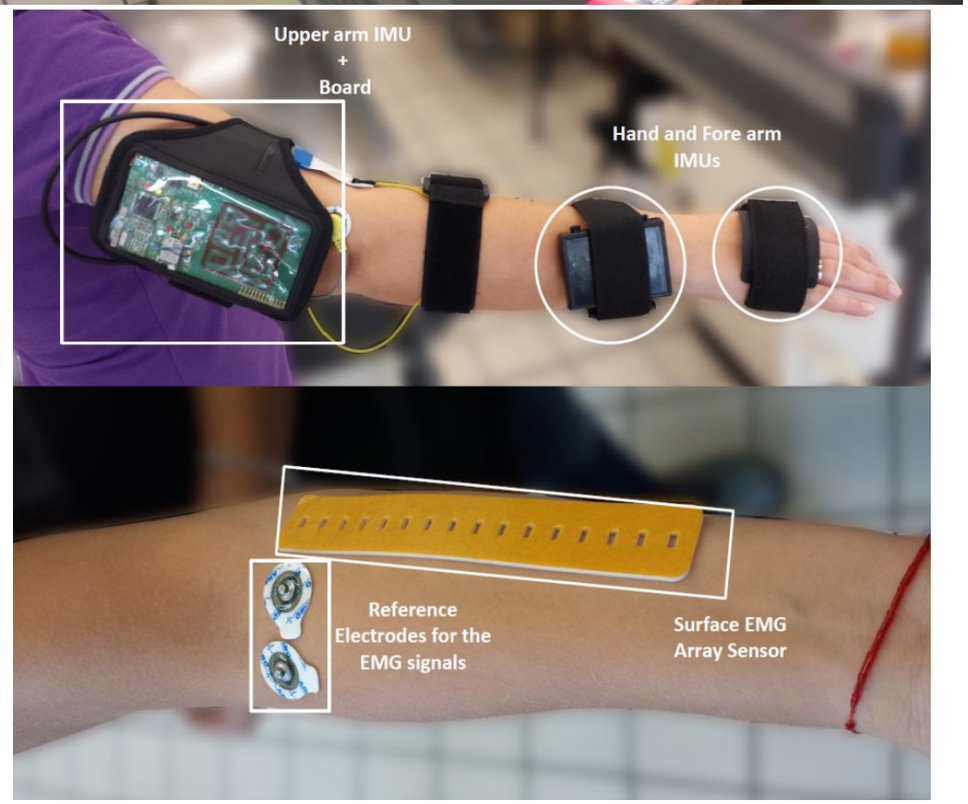
Muscular activation triggers

Muscular activity intensity measurement

Experimental Setup

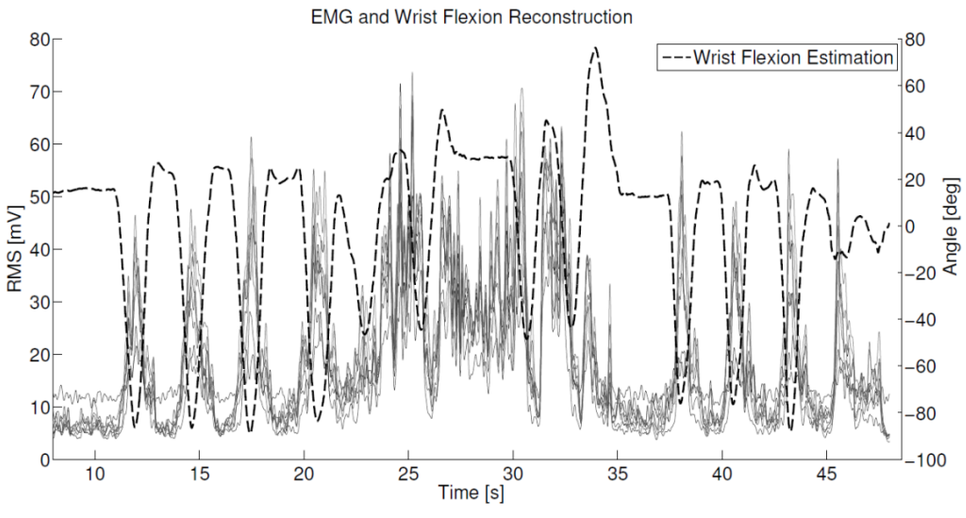
Method:

- Participant: 1 healthy cashier
- Equipment
  1. board with 8 EMG, 4 IMUs
  2. RGB-D sensor (MS Kinect)
- Task: 2x10 minutes having either
  1. random customer bag
  2. known bag
- Procedure
  1. Familiarization
  2. Calibration
  3. Capture



Captured data and reconstruction

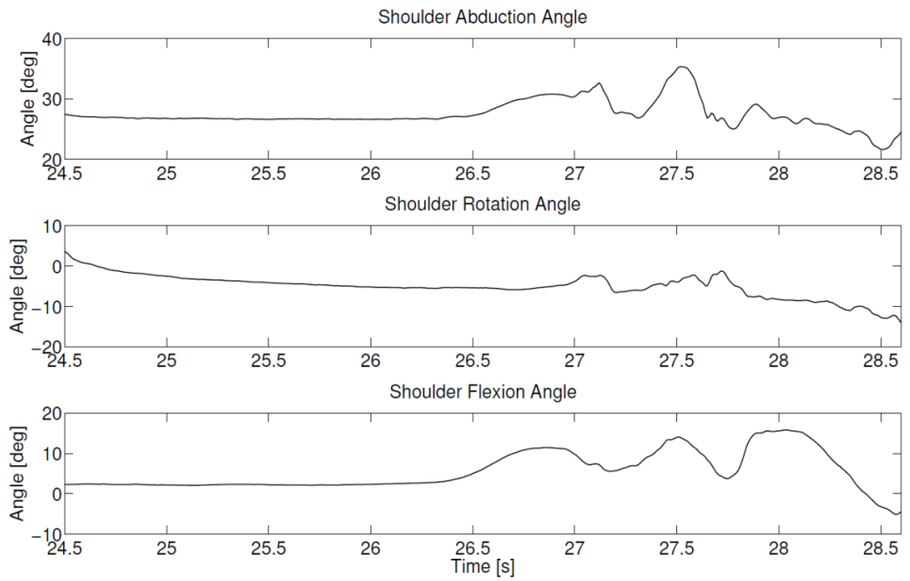
EMG Bandpower and Wrist motion

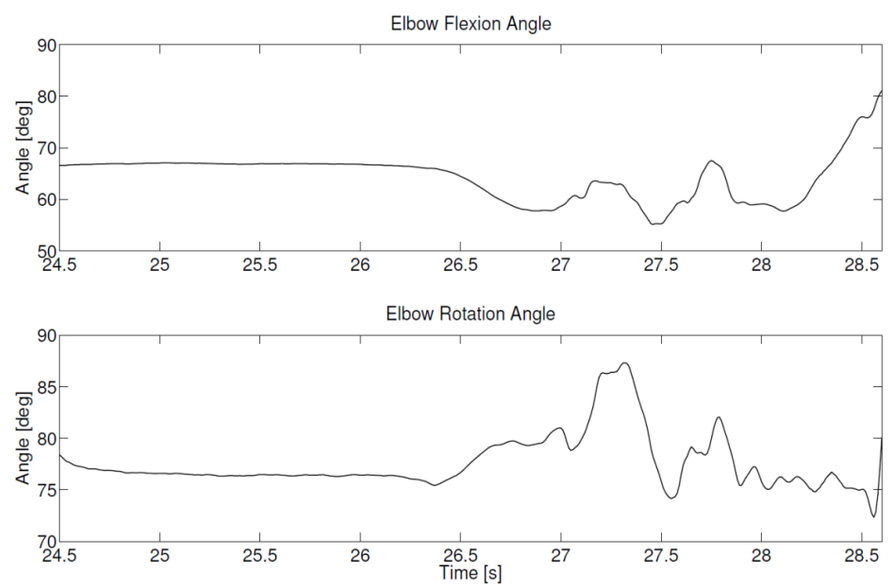


Item List

Item	Weight [Kg]
Coke cans pack	2.160
Bisquits pack (small)	0.270
Tuna cans pack	0.440
Cornflakes pack	0.365
Tea bottle	1.620
Potato bag	4.020
Bisquits pack (big)	0.510

Posture





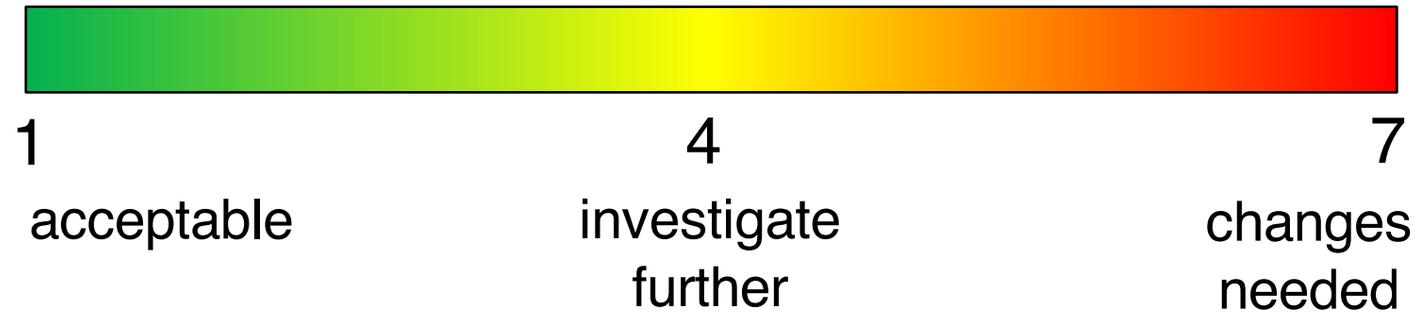
Ergonomic assessment results

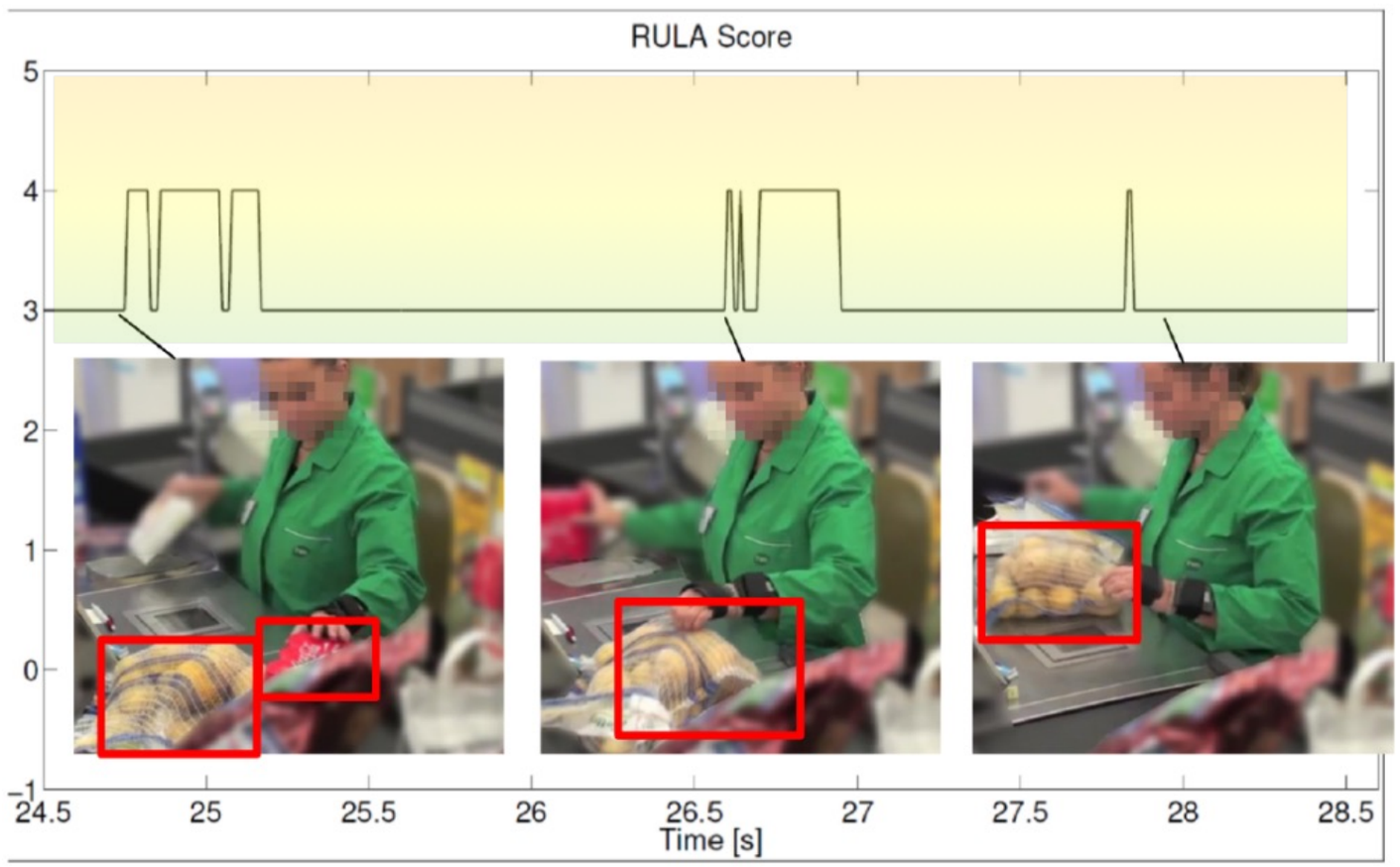
Variables:

- Shoulder angles
- Elbow flexion
- Wrist angles
- Arm score
- Leg score
- Load to be handled
- Load static or dynamic flag
- Neck flexion (here 0)
- Neck bending flag
- Trunk bending flag
- Trunk flexion flag
- Arm support flag
- Leg support flag

RULA score

$$RS = f(sh, e_f, wr, a_{ms}, l_{ms}, F, F_{fl}, a_{sup}, n_f, n_e, t_e, t_f, l_{sup})$$





Conclusion and future work

Conclusion

- Wearable system for ergonomic assessment
- Acquisition and processing of sEMG signals
- Acquisition and processing of motion data
- Ergonomics score in ecological conditons

Future Work

- Extended assessment of the automatic RULA score
- Online assessment

thank you!

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